THE HIGH SPEED ELECTRONICS GROUP

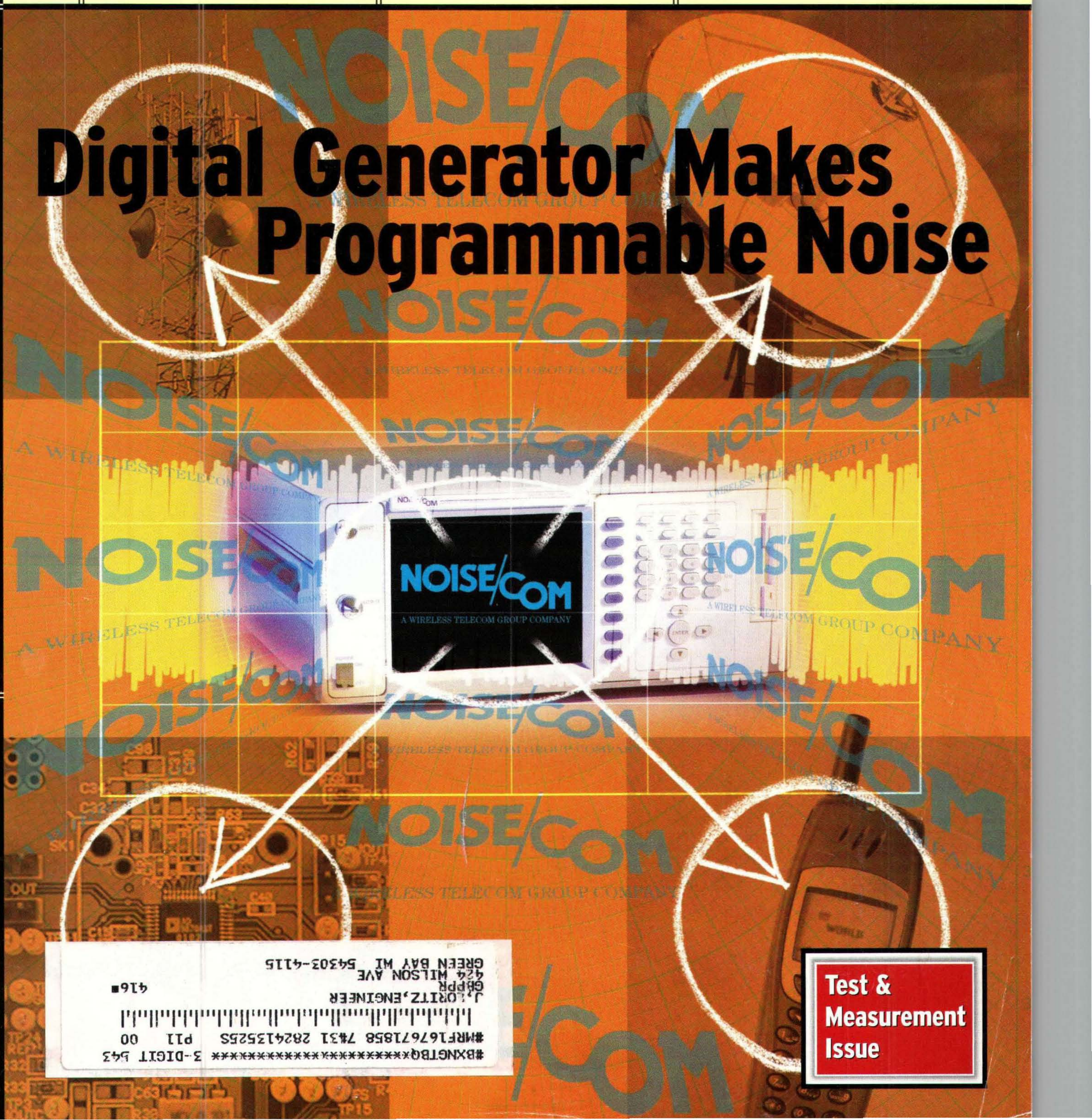
Microwaves & RF

News
TIAs clear way for 40-Gb/s systems

Design Feature
Understand Bluetooth protocol testing

Product Technology
Software helps visualize system performance

Digital Generator Makes Programmable Noise



Test & Measurement Issue

JANUARY 2002 • VOL. 41 • NO. 1

Microwaves & RF

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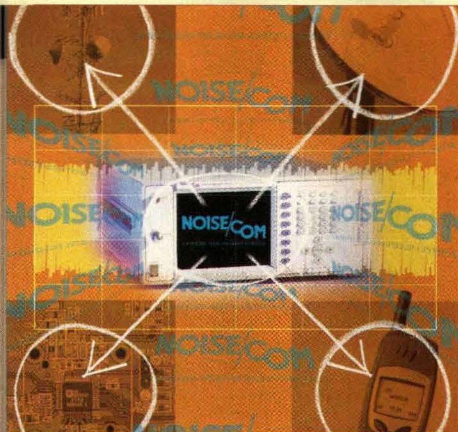

COVER STORY

The first member in this series of digital noise generators offers a 70-MHz bandwidth with 1-Hz resolution for noise waveforms and 1-kHz resolution for CW waveforms.

News

Design

Product Technology

Penton

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Informative Issue

▶▶I AM IN the process of reading your August 2001 issue that focuses on microwave and RF history over the last 40 years and find it interesting. Coincidentally, I started in the RF field 40 years ago.

Your comments regarding people such as Traut, Rose, Cheney, and others are also extremely interesting. It is a wonder to think of all of the electronic marvels that have occurred with those people who accomplished their deeds without the aid of computers, CAD systems, and more.

Your editorial should be required reading for so many of today's engineers and managers. What is more important—logical, functioning, imaginative minds, or the ability to use computer-generated equipment?

Personally, I find that particular question to also be interesting. Thank you for a very informative issue.

Pat Petti

False Promises

▶▶A LOT OF MAGAZINES frustrate me. They have things on the cover that are not inside, they put page numbers in funny places, or omit them from multiple pages of an article. Yet, they define common terms such as "CMOS," but omit ones in articles on new modulation schemes. You get the picture.

For instance, the September cover promises to tell me about "Linear HBT Amplifiers Arrive From New Source." Oh yeah? It does not appear in the Table of Contents or under "New Products," and it is not under "Product Technology," where it should be. I think those magazines that hype something on the cover should, on the cover, include the page number where the story can be found.

I guess to be fair, there are fewer mathematical errors in your magazine. Either that, or you do not publish corrections.

Doug McGarrett
Senior Engineer
Ademco

Editor's Note: *The story that was referred to on the September cover actually did appear in the Product Technology section in that issue on page 124. The main problem was that the Table of Contents listed the wrong Product Technology feature for page 124. The Product Technology feature that was listed ran in the August issue, but its headline was duplicated into September's Table of Contents. Our apologies to our readers for this error. Also, for us to not publish corrections of any sort is an injustice to our readers. We try our best to not make mistakes, but they do happen from time to time.*

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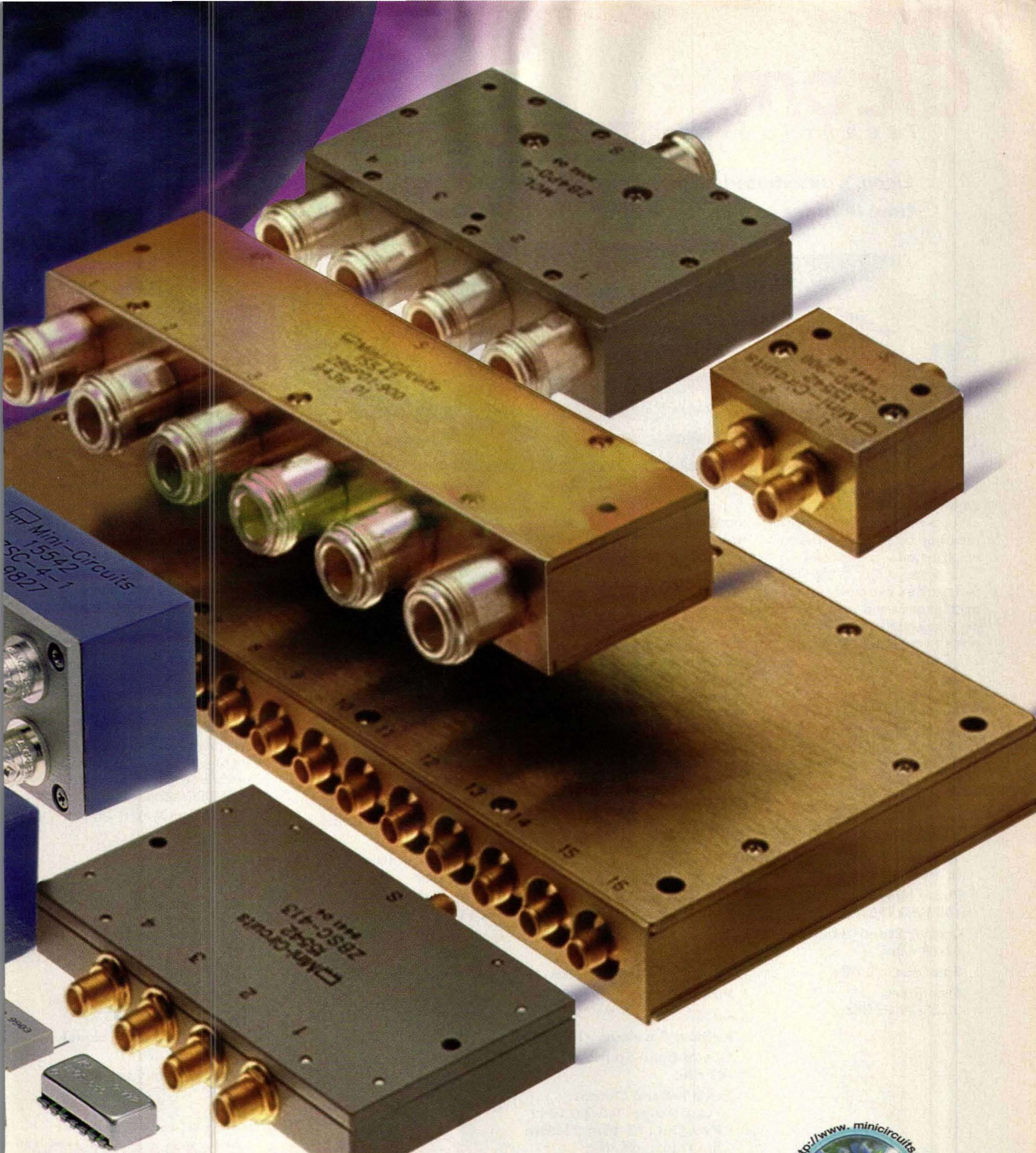

Embracing A Year Of Promise

Each new year should bring with it hope for new beginnings, for positive change, and for growth. Without hope, life would be a meaningless struggle. But with hope, there is always that "next chance," that opportunity to get something right or to achieve some goal that has remained elusive. And with the kind of year that many of us have endured during 2001, the healthiest attitude is one where the tragedy and disappointments of 2001 are added to that long list of items known as "experience," and the knowledge is used to make a better tomorrow.

If 2001 taught the staff of this magazine anything, it was that nothing should be taken for granted. It was a year in which many companies cut back on advertising expenditures, and magazines, such as this one, became smaller as a result. Developments in high-frequency engineering did not slow down in 2001, but the magazine "real estate" available to publish some of these developments diminished during the year and less articles were published.

Developments in high-frequency engineering did not slow down in 2001, but the magazine "real estate" available to publish some of these developments diminished during the year and less articles were published.

As a way of apologizing to the many authors who had seen the publication of their article delayed during 2001, the new year will bring with it what might be termed "an experiment in publishing." Engineers need to stay abreast of the latest developments, or they risk the chance of duplicating something developed elsewhere. Since the Internet knows no practical limits, it is a logical extension of any printed magazine. So in 2002, look for the expression "the full-length version of the article is available on the *Microwaves & RF* website at www.mwrf.com" to appear in the printed magazine. It directs readers to the magazine website for additional information that does not appear in printed form, but which is of potential value to the engineering readership.

This is a way of making the best of a difficult situation. Many readers have said they like the feel of a book in their hands compared to reading an article on a computer screen. This compromise provides tightly edited articles in the printed magazine, and additional information is available on the Internet at the reader's convenience. Hopefully, it is an approach that helps guide our readers through a successful 2002.

Some of the editorial calendar themes for this year are: fiber-optic technology, wireless technology, passive components, military electronics, frequency generation/control, and communications.

Jack Browne

Publisher/Editor

Microwaves & RF

A Penton Publication

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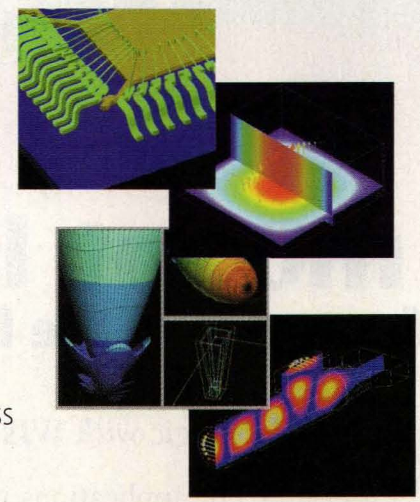

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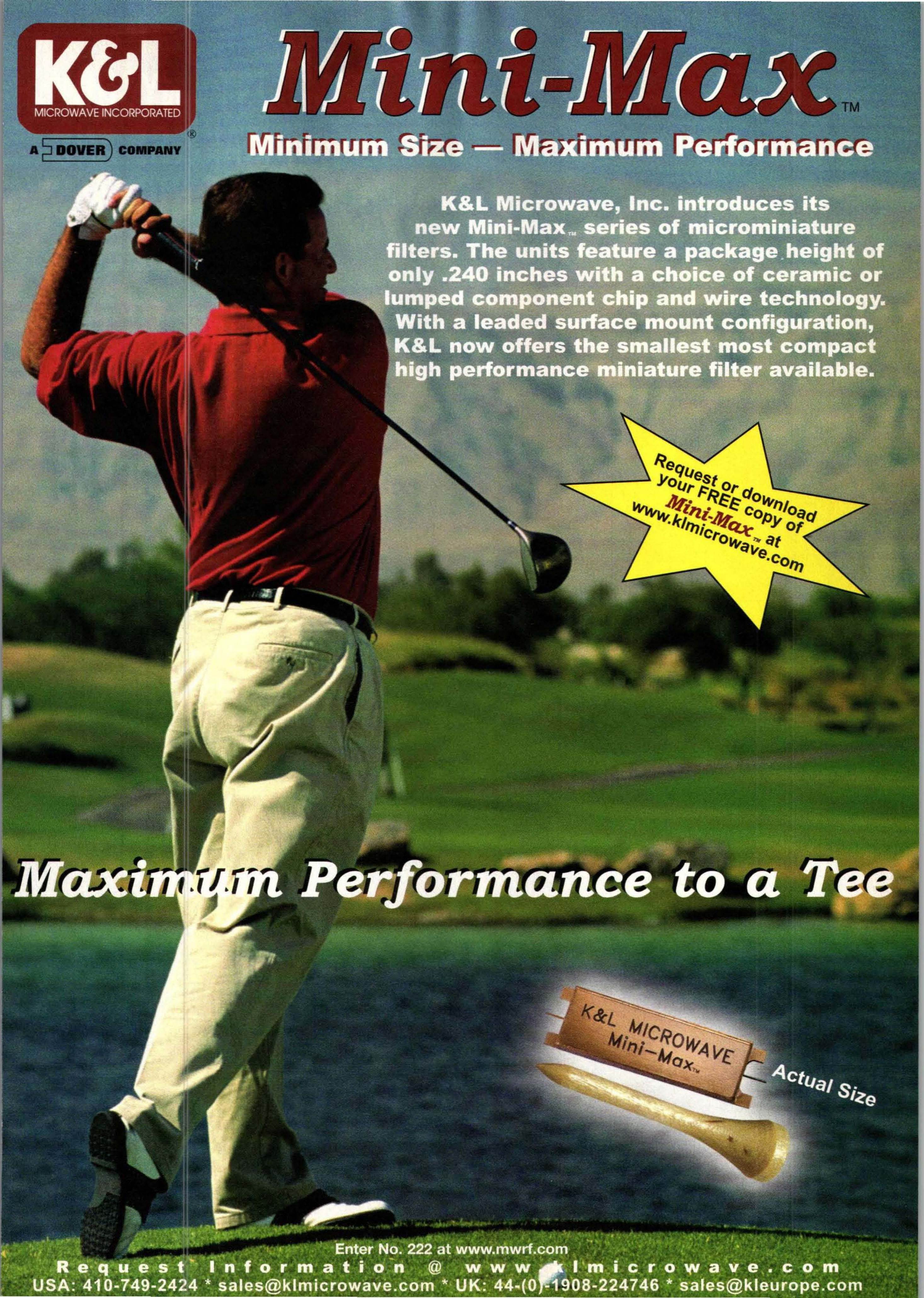
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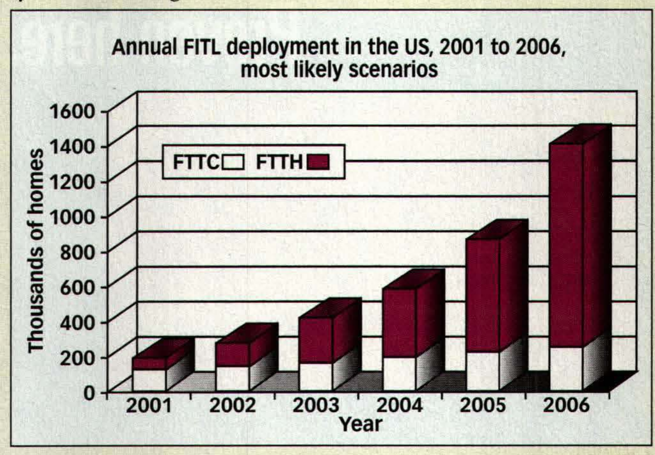
the front end

News items from the communications arena.

Fiber To The Home Will Reach 2.6 Million Homes By 2006

PROVIDENCE, RI—Fiber-to-the-home (FTTH) systems in the US will reach 2.65 million homes by 2006, with fiber-to-the curb (FTTC) systems reaching another 1.9 million, according to *Residential Broadband Access in the United States: Fiber-to-the-Curb and Fiber-to-the-Home,* a report from KMI Corp. As of year-end 2001, FTTH and FTTC are expected to reach 89,000 and 915,000 homes, respectively. During this same time frame, annual deployment of FTTH is expected to increase from 66,000 in 2001 to 1.15 million homes in 2006—a 63-percent compound annual growth rate (CAGR), with FTTC expecting a more modest 15-percent CAGR from 130,000 homes in 2001 to 260,000 in 2006 **(see figure)**.



To date, FTTH has been primarily deployed by three types of carriers: rural incumbent local-exchange carriers (ILECs), competing carriers, often working with real-estate developers, and small-town governments.

FTTC has been deployed largely by one regional Bell operating company (RBOC) with smaller deployments by rural ILECs and by competing carriers.

The FTTH market is expected to grow significantly in 2006, with a ramp up beginning in 2005. In the next four to five years, market demands and cost factors are expected to drive most or all of the RBOCs to begin FTTH deployment in new housing developments, then in network rebuilds. This will drive the market from 66,000 new homes served in 2001 to 1.15 million new homes served in 2006.

mHEMT Foundry Process Has Transitioned Into Production

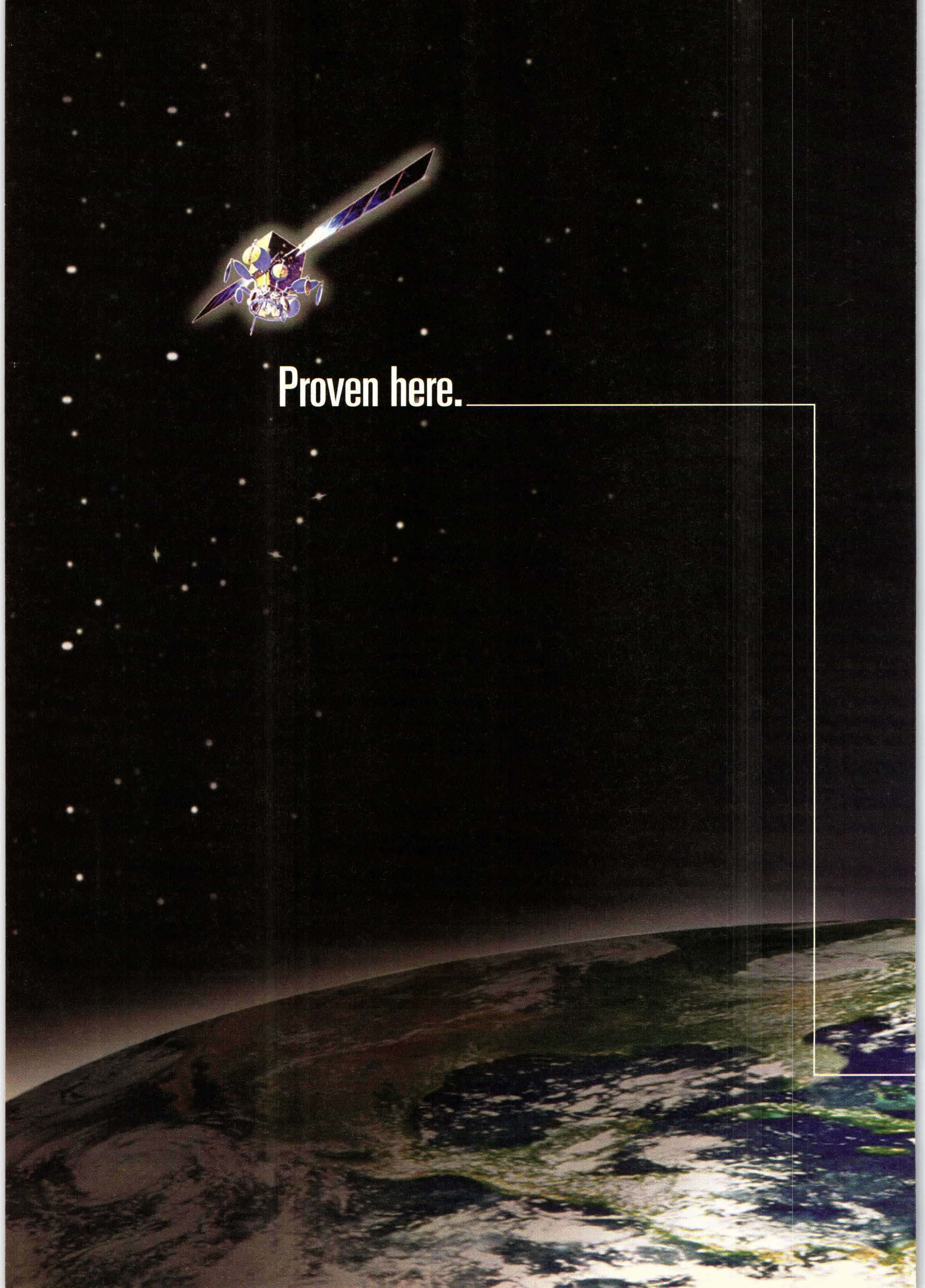
ANDOVER, MA—Raytheon Co.'s RF Components Division has announced that their 4-inch Metamorphic High Electron Mobility Transistor (mHEMT) foundry process for microwave and millimeter-wave applications has transitioned into production.

The announcement was made by RRFC vice president of business development, Russ Wagner, who says that the process significantly improves the manufacturability and lowers the cost of indium-phosphide (InP) HEMT devices compared to alternative structures.

According to Wagner, process results have shown excellent linearity, gain, and noise performance, making mHEMT suitable for such applications as wide bandwidth amplifiers (TWA's) for fiber-optic receivers (Rxs), low-noise millimeter-wave Rxs, and automotive radar systems at 77 GHz and above.

One of the major advantages of the mHEMT process is that it achieves the high electron velocity normally only found on InP HEMTs without the additional expense and manufacturability issues associated with InP substrate-based devices.

During growth, a metamorphic buffer layer transforms the lattice from gallium arsenide (GaAs) to In0.53GaAs through controlled dislocation creation, allowing the strain-free growth of thick, high indium content devices on manufacturable GaAs substrates. The high indium content channel and Schottky layers offer many desirable properties such as high mobility, high peak velocity, and better quantam-well confinement.


Proven here.

> "At the moment, it's just a proof of principle that a single molecule can do the job."

Acquisition Increases Process-Technology Portfolio

GREENSBORO, NC—RF Micro Devices, Inc. has agreed to acquire RF Nitro Communications, Inc., a privately held company with advanced materials and products in broadband wireless and wire-line (fiber-optic) markets. Terms of the transaction were not disclosed.

The acquisition will increase RFMD's portfolio of process technologies, expand its product offerings, and is expected to significantly strengthen its competitive position in the wireless infrastructure market.

William Pratt, RFMD's chairman and chief technical officer, says, "We believe the acquisition of RF Nitro will greatly strengthen our technology leadership position. Through RF Nitro, we will gain instant access to advanced compound semiconductor processes, such as gallium nitride (GaN), as well as additional resources to conduct advanced research on this and other technologies.

"We believe GaN to be a disruptive and revolutionary technology in wireless infrastructure applications. Since July 2001, RF Nitro has sold prototype quantities of GaN power transistors that exhibit power density approximately one hundred times greater than silicon. Using GaN, base-station power amplifiers may be built to operate at very high voltages and at higher efficiency and better linearity than existing designs using LDMOS technology. In addition to GaN, RF Nitro produces and sells InGaP transistors and amplifiers, and we expect their expertise in this area will accelerate our previously announced initiatives to introduce InGaP for certain wireless applications."

RF Nitro's operations include a four-inch wafer-fabrication facility, which will be used for production and as a technology incubator. The company also operates design, assembly, and test facilities.

The GaN technology was developed under a government-sponsored ONR-MURI program by Cornell University over the last six years. During the program, Cornell demonstrated world-record power density of 11.2 W/mm at 10 GHz and +45-VDC operation. In addition, Cornell has successfully built GaN devices on silicon. RFMD will receive from Cornell Research Foundation an exclusive license agreement in all fields of use, including electronics and opto-electronics, for all applications, including power switching and RF amplification, as well as lighting.

Scientists Build Transistor Made Of One Molecule

NEW YORK, NY—Scientists have observed single molecules acting as transistors, the tiny electric switches that form the brains of computers, according to a report from Reuters.

In an article published in the journal *Science,* researchers from Bell Labs said that they had built layers made up of thousands of organic molecules with just one or two "electrically active" components.

The process is an enhancement to a process announced by the same researchers a month ago. At the time, the team described a chemical process that makes layers of organic material only one molecule thick that can be used to form simple electric circuits.

The scientists said that they had tweaked the chemical process to create the same kind of molecular layer but with precisely one or two active molecules, known as thiols, that serve as the basis for a transistor.

Jan Hendrik Schon, the lead researcher, said that the team can identify the thiols amid the thousands of inactive molecules, but cannot yet pick them out and put them together.

"At the moment, it's just a proof of principle that a single molecule can do the job," says Schon. "We don't have the tool . . . to precisely put a molecule in a certain space."

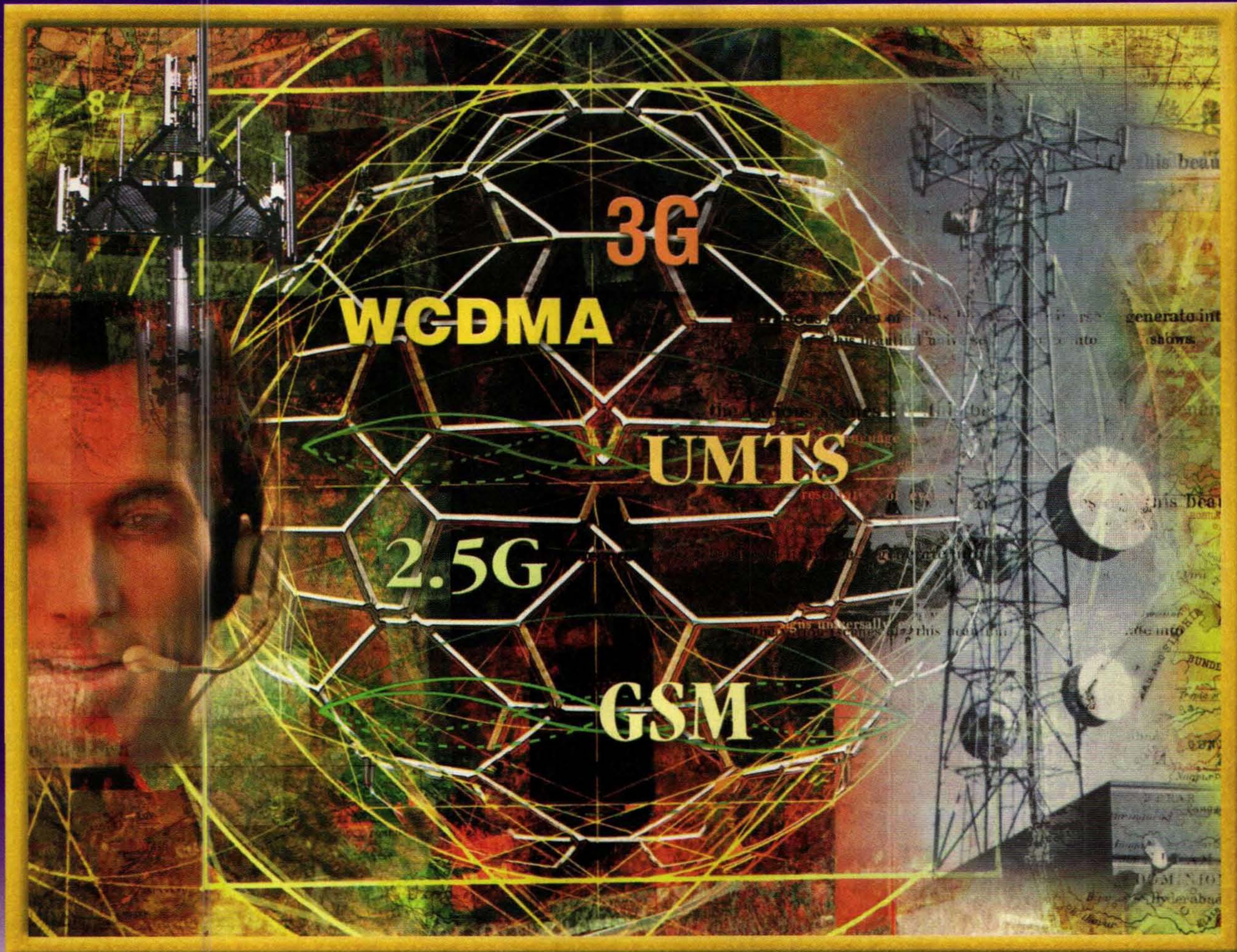
Bell Labs, a research facility of Lucent Technologies, Inc., was the original inventor of the transistor and has generated more than 28,000 patents since 1925.

Japan's Mobile-Phone Users Now Total 66 Million

TOKYO, JAPAN—According to a Reuters report, the number of Japan's cell-phone users rose to 66 million in October, up 17 percent from a year earlier. This confirms wireless services as one of the fastest-growing areas of the Japanese economy.

Of the total 65.92 million, 46.18 million subscribers has Internet-enabled mobile phones, up 2.8 percent from September, and up 111.8 percent from a year earlier.

The number of subscribers of Japan's top wireless carrier, NTT DoCoMo, Inc., totalled 38.84 million at the end of October, of which 28.64 million used 'i-mode,' the system that allows Web surfing on business-card-sized screens.


3G
WCDMA
UMTS
2.5G
GSM

Wireless Baseband Chip Is Produced Using 300-mm CMOS Fabrication

SAN DIEGO, CA—Qualcomm, Inc. announced that it has received the first test samples of the company's third-generation (3G) MSM6050™ Mobile Station Modem (MSM™) device. The MSM6050 device is the first wireless baseband chip produced using state-of-the-art 300-mm (12-in.) complementary-metal-oxide-semiconductor (CMOS) fabrication from Taiwan Semiconductor Manufacturing Co. Ltd. (TSMC).

The MSM6050 chip set and system software is QCT's highly integrated next-generation cdma2000 1X product, which will offer increased processing power in a mid-tier 3G solution that doubles system voice capacity over previous IS-95A/B solutions, supports data rates of up to 153 kb/s, and integrates QCT's radioOne™ Zero Intermediate Frequency (ZIF), or a direct-conversion architecture.

The MSM6050 solution also offers gpsOne™ position-location capabilities and the advanced feature set of QCT's Wireless Internet Launchpad™ suite of technologies, offering a rich mixture of multimedia, connectivity, position location, user interface, and storage capabilities. In addition, the MSM6050 chip supports Qualcomm's Binary Runtime Environment for Wireless™ (BREW) applications platform.

With the rapid growth of code-division multiple access and the acceleration of deployment of 3G cdma2000 1X networks, demand for next-generation MSM6050 chip sets is expected to grow significantly. Use of 300-mm fabrication lines, with the latest fabrication processing equipment, provides more than twice the number of parts per wafer compared to traditional 200-mm fabrications, meaning that fewer wafer starts are needed to support increasing volumes of product.

Deliveries Of Space-Station Antennas Are Completed

"The antenna is used for all high-data-rate transmissions and receptions to the International Space Station."

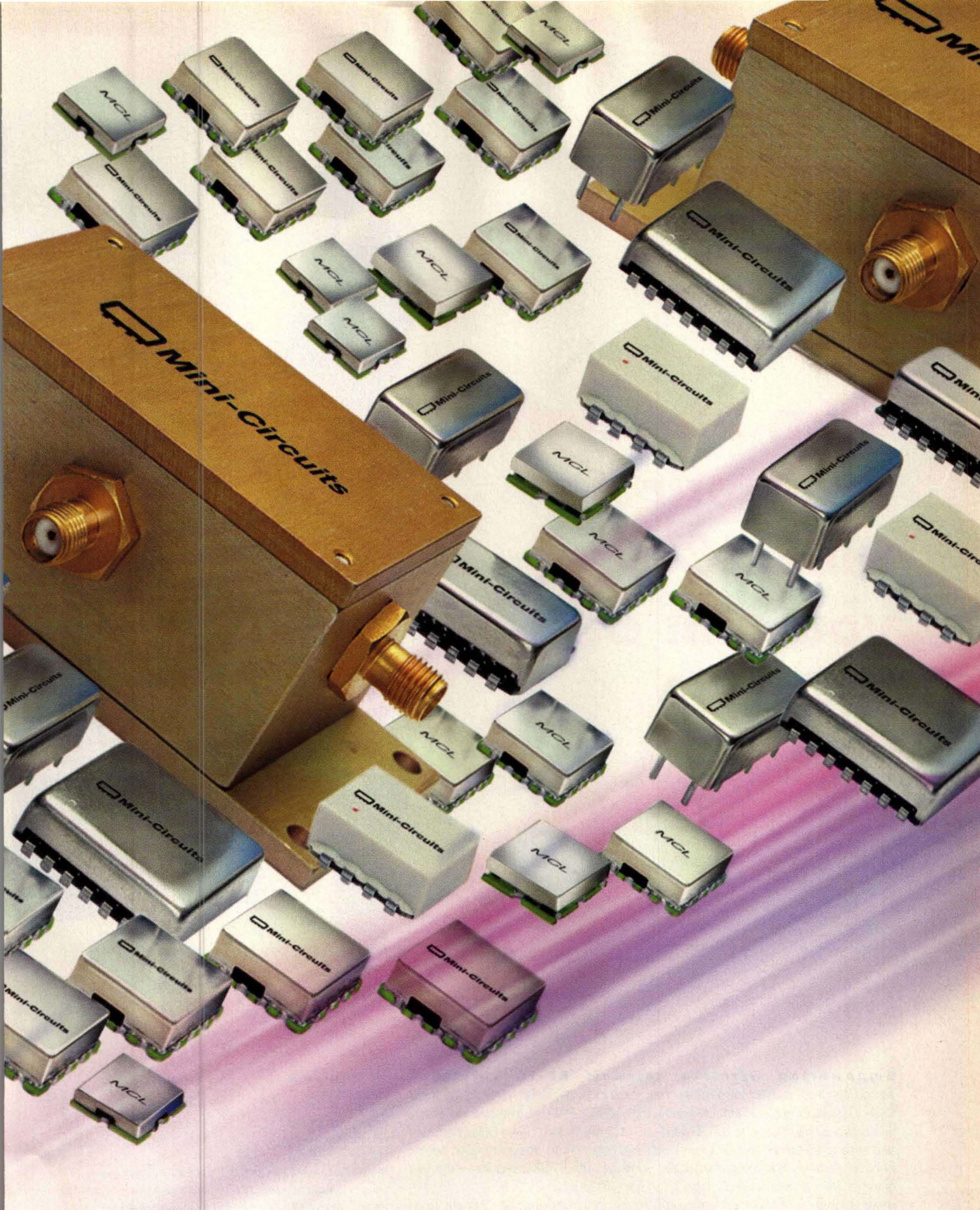
ATLANTA, GA—EMS Technologies recently delivered a spare high-gain antenna for the International Space Station (ISS). This space-to-ground antenna, capable of data rates of up to 75 Mb/s, is used for all high-data-rate transmissions and receptions to the ISS. Its 74-in. (188-cm) diameter parabolic cassegrain reflector carries multichannel video as well as high-speed scientific data.

Using sophisticated materials (titanium, carbon fiber, and kevlar), the gimbaled Ku-band antenna automatically tracks NASA's Tracking and Delay Relay Satellite System. Its functionality complements the gimbaled S-band antennas, a criticality-1 system used for low-data-rate telecommunications, telemetry, and command (TT&C). Two S-band antennas and one Ku-band antenna have already been launched, delivered, and installed on board the ISS, ensuring complete bidirectional space-to-ground-to-space communications coverage.

This delivery is the final shipment of communications antennas for the ISS. A total of three S-band (two on-orbit and one ground spare) and three Ku-band antennas (one on-orbit and two ground spares) have now been delivered from EMS Technologies' Space & Technology Group in Montreal.

Kudos

NetVendor, a provider of collaborative commerce solutions, announced that it has been included in the "Computerworld Top 100 Emerging Companies for 2002." To select the Computerworld Top 100 Emerging Companies for 2002, a panel of *Computerworld* editors and a select group of information-technology (IT) industry influencers representing senior-level executives—who are providers and users of IT—reviewed nominations from for-profit ventures with revenue of less than $250 million and founded no earlier than 1996...Hybrid Networks, Inc., a firm involved in multichannel-multipoint-distribution-service (MMDS) fixed broadband wireless Internet-access systems, announced that it is ranked at No. 476 on the 2001 Deloitte & Touche Technology Fast 500, a ranking of the 500 fastest-growing technology companies in North America. Rankings are based on five-year percentage revenue growth from 1996 to 2000. Hybrid Networks grew 910 percent during this period...The New Jersey Institute of Technology (NJIT) has opened New Jersey's first College of Computing Sciences. The school is one of the nation's largest colleges of computing sciences with more than 2400 enrolled undergraduate, master's, and doctoral students. To create the college, NJIT upgraded the status of the department of computer and information science, formerly part of the College of Science and Liberal Arts. MRF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P/N	Description	Application
U7004B/ U7006B	1.9-GHz PA + LNA	DECT RF Front End
T0930	900-MHz PA	2-way pager
TST0950	900-MHz LNA	GSM, ISM
TST0912	900-MHz PA	GSM
TST0951	1900-MHz SiGe LNA	DCS & PCS mobile phones
T7024	2.4-GHz SiGe Front End	ISM/Bluetooth
T0980	400/500-MHz SiGe Front End	Family radio (Walky Talky) & remote control applications

PA: Power Amplifier
LNA: Low Noise Amplifier

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NEWS

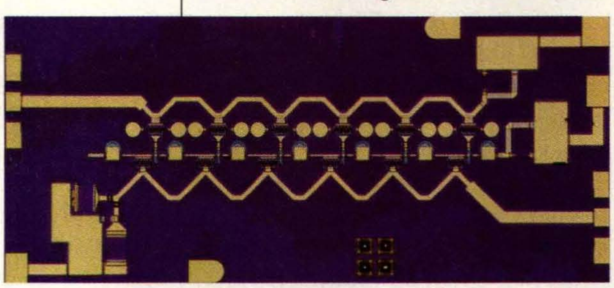
TIAs Clear Way For 40-Gb/s Systems

The transimpedance amplifier (TIA) is a key component as optical-communications systems push for 40-Gb/s performance.

BARRY MANZ
President
Manz Communications, 350 Main Rd., Montville, NJ 07045; (973) 316-0999, FAX: (973) 335-7857, e-mail: manzcom@erols.com, Internet: www.manzcom.com.

Bandwidth is precious, and essential to a future with high-speed information sharing, data transfer, and "instant" Internet access. For optical-communications systems to achieve their promise of 40-Gb/s performance and beyond, the transimpedance amplifier (TIA) performs far beyond its traditional limits. The TIA's visibility will become even greater as data rates move to 10 Gb/s in Synchronous Optical Network (SONET) OC-192 and to 40 Gb/s in OC-768, as in Ethernet applications.

In high-speed optical-communications systems, TIAs boost low-level signals from a photodetector for further processing in an optical receiver (Rx). TIAs can be characterized by a number of parameters, including bandwidth, transimpedance gain, and equivalent input noise current. A TIA's 3-dB bandwidth determines its highest achievable data rate, while transimpedance (gain) is the change in output voltage that is produced by a change in input current. The equivalent input-noise current (or density) is derived from the noise power that is realized in a stated bandwidth, and directly determines the minimum usable signal (minimum sensitivity) that can be processed by the amplifier.



1. The model RMLA00400 traveling-wave amplifier is designed for 40-Gb/s optical systems. The amplifier delivers 16-dB gain from 40 Hz to at least 40 GHz, with ±0.75-dB ripple, noise figure of 2 dB to 35 GHz, and noise-current density of 25 pA√Hz. (Photograph courtesy of Raytheon Co., Andover, MA.)

Since a TIA works directly with the output current from a photodetector (without a blocking capacitor), conventional input circuits are not used as they are with other general-purpose amplifiers. In many applications, the TIA drives an automatic-gain-control (AGC) amplifier before signal regeneration, and the output circuit for the amplifier is usually a 50-Ω transmission line. At 40 Gb/s, proper matching of the TIA to the photodiode is critical. It is also essential that all of the characteristics of the TIA, photodiode, and other Rx components be considered simultaneously, with special attention being paid to the control of parasitic-circuit elements.

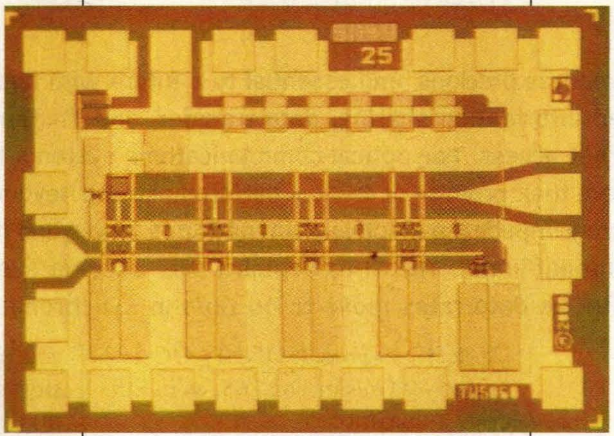
Efforts to increase the data rate of Ethernet and Fibre Channel systems from 1 to 10 Gb/s and for bringing

OC-192 (10 Gb/s) and OC-768 (40 Gb/s) SONET to the metropolitan and long-haul common-carrier markets are the greatest drivers of TIA development. The 10-Gb/s Ethernet market alone is a potentially enormous opportunity for TIAs, and analysts generally predict the addition of new Ethernet ports at 10 Gb/s to increase from approximately 250,000 ports in 2002 to more than 5 million ports in 2005. The cost of 10-Gb/s Ethernet is likely to drop from approximately $1.00/Mb of data today to perhaps $0.60/Mb in 2004.

While such rosy projections show broad short-term promise, the optical-components marketplace actually contracted significantly during 2001, by up to 50 percent in some sectors. As a result, there are currently more manufacturers of TIAs than there are sockets in which to place their products. At the 10-Gb/s benchmark just being realized today, where complementary metal-oxide semiconductor (CMOS), gallium-arsenide (GaAs), and silicon-germanium (SiGe) are the semiconductor compounds of choice for TIA design, there are at least two dozen companies that have either announced 10-Gb/s TIAs or plan to do so. That number will surely be reduced in the next two years, as the real demand for 10-Gb/s sockets emerges, according to representatives of most manufacturers contacted for this report.

Thomas Lagatta, vice president and general manager of ANADIGICS (Warren, NJ; www.anadigics.com) neatly summarized its projections for higher-data-rate implementation. The company has coined "Library of Congress" as a way to graphically demonstrate the enormous amounts of data handled by enterprise, metro, and long-haul networks. One Library of Congress equals transferring the entire contents of the library (18 million books). According to ANADIGICS, one complete transfer equivalent to the Library of Congress will be transferred every second in North America alone.

Projections used by ANADIGICS illustrate the rapid and enormous increases in traffic that are occurring on global-communication networks. In 1999, according to data supplied by Pioneer Consulting, worldwide bandwidth demand was 0.6 Tb/s. This tripled to 1.9 Tb/s in 2000 and is projected to reach 5.7 Tb/s in 2001. From here, bandwidth demand doubles (rather than triples), to reach 43 Tb/s by 2004. Ethernet local-area networks (LANs) in North America alone transfer 15 EB of data per month—or, in ANADIGICS terms, 750 Library of Congresses—impeded by the metro-area network, which presents a bottleneck to further increases, and an opportunity for optical-component suppliers.



2. The model ATA7702 traveling-wave amplifier is based on InP HBT technology and designed for 40-Gb/s systems. (Photograph courtesy of ANADIGICS, Warren, NJ.)

"The capability of the backbone today far exceeds the current demand of traffic in 2001, so 70 percent of the installed fiber is still dark," says Lagatta. "Around 2003, demand will grow to choke the backbone, which points to added capacity in the second half of that year. The metro-area network is absolutely choking the rate at which data gets to the end user," Lagatta continues. "Our view is that for the next 12 to 18 months, capital will be spent in metro SONET rings and a longer Ethernet mesh to correct this problem. This capital expenditure is what will open up more data to the backbone, which will choke it and drive the market to 40 Gb/s."

Another driver of 10-Gb/s Ethernet is storage networking, which continues to show signs of life even amid the current economic downturn, a direct result of the widespread adoption of the storage-area networks (SANs) for shared data storage, and the growing likelihood that Ethernet, along with the iSCSI protocol, will be the technologies of choice when 10-Gb/s data rates are achieved in the SAN environment. SANs are currently powered almost exclusively by Fibre Channel, but when and how efficiently Fibre Channel makes the jump from its current 2-Gb/s speed to 10 Gb/s is the subject of speculation.

The frontier for advanced TIA development begins at 10 Gb/s, where the advantages of GaAs, SiGe, and indium phosphide (InP) provide significant benefits. TIAs for 10-Gb/s operation are available from a large number of manufacturers, and still others are entering the marketplace.

Phillips Semiconductors' (Sunnyvale, CA; www.semiconductors.phillips.com) model CGY2110AUH/C1 10-Gb/s TIA is a representative example. The GaAs pseudomorphic-high-electron-mobility-transfer (PHEMT) device features typical transimpedance gain of 66 Ω, noise of less than 9 pA/√Hz, as well as power consumption of 350 mW at +5 VDC. Phillips offers the CGY2110AUH/C1 as a bare die.

Models VSC7997 and VSC7998 from Vitesse Semiconductor (Camarillo, CA; www.vitesse.com) are designed for SONET/synchronous-digital-hierarchy (SDH) applications and have 5.0- and 1.4-kΩ differential transimpedances, respectively, a sensitivity of −18 dBm, and 2.2-mA maximum input current. The devices consist of a transimpedance stage and a single-to-differential output stage with a gain of 20 dB, and can be AC or DC coupled. The output of both devices is linear for inputs up to 250 μA peak-to-peak and, at higher inputs, output is limited at 1000 mV peak-to-peak, which increases system dynamic range by reducing the chance of exceeding the input voltage range of

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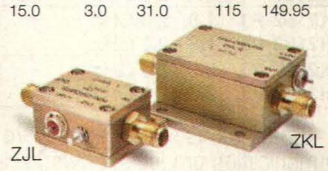
SPECIFICATIONS

Model	Freq (MHz)	Gain (typ) Midband (dB)	Gain (typ) Flat (±dB)	Max. P_{out} 1 (dBm)	Dynamic Range (Typ @2GHz 2) NF(dB)	Dynamic Range (Typ @2GHz 2) IP3(dBm)	I(mA) 3	Price $ea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5	32.0	80	129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0	24.0	50	99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5	30.5	75	129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5	24.0	50	114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5	30.5	75	129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8	22.0	45	114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0	30.0	120	149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0	31.0	120	149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0	31.0	120	149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0	31.0	115	149.95

NOTES:
1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.



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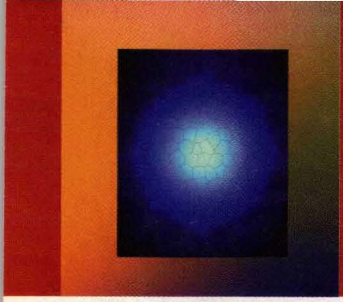

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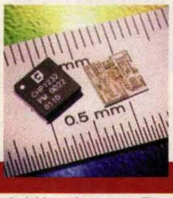

TrueTriangle

New 50 Ohm matched, 6mm square, power amplifier modules for cellular, PCS, DCS, wireless local loop and other high bandwidth wireless data applications. These new InGaP HBT amplifier modules are a part of Celeritek's TrueTriangle™ family and are less then half the size of comparable solutions, integrate (14) supporting components, and has been specifically developed to meet the continuing requirements for small, low-cost, high capacity wireless voice and data applications.

InGaP HBT Single Supply Modules

Model Number	Frequency Range	Pout (+dBm)	Efficiency (%)	Associated Gain (dB)	Supply Voltage (V)	Package
CHP0230-PM	824 to 849 MHz	28.5 (CDMA)	38	30	3.5	6mm PM
		30 (TDMA)	42	29	3.5	
		31.5 (AMPS)	50	26	3.5	
CHP1230-PM	1720 to 1780 MHz	28 (CDMA)	33	30	3.5	6mm PM
CHP1232-PM	1850 to 1910 MHz	28.5 (CDMA)	35	30	3.5	6mm PM
		30 (TDMA)	39	30	3.5	
CHP2230-PM	1920 to 1980 MHz	26 (WCDMA)	35	30	3.5	6mm PM

Fixed Wireless & Wireless LAN Amplifiers

Model	Frequency Range	Application	Power Output (+dBm) Typ	Power Added Efficiency (%) Typ	Small Signal Gain (dB) Typ	Drain Voltage (V) Typ	Drain Current (mA) Typ	Package Type
CMM3008-AH	30 kHz - 8.0 GHz	Ultra Broadband	14	—	14	+3	50	AH
CMM6004-AH	0.25 - 6.0 GHz	Fixed Wireless & WLAN	23	50	18	+5	180	LGA
CMM6025-AH	30 kHz - 8.0 GHz	Fixed Wireless & WLAN	25	—	16	+3	350	AH
CMM6027-AH	30 kHz - 8.0 GHz	Fixed Wireless & WLAN	27	—	15	+5	370	AH
CMM2305-AR	800 MHz - 2.7 GHz	Driver	17	—	20	+5	70	MSOP-8
CMM2306-AJ	800 MHz - 2.7 GHz	Driver	17	—	20	+5	70	SOIC-8
CMM2308-AJ	800 MHz - 2.7 GHz	High Dynamic Range	17	—	19	+5	70	SOIC-8
CMM1321-AK	1.85 - 2.0 GHz	PCS	30	50	24	+5	500	SO-8
CMM2321-AK	2.4 - 2.5 GHz	ISM	30	30 – 52	20	+5	675	SO-8
CMM3566-AK	3.45 - 3.50 GHz	W-CDMA	22	—	28.5	+7	500	SO-8

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Celeritek introduces a new family of driver amplifiers for external fiber optic modulators targeting high bandwidth applications. The **WideFiber™** product family leverages Celeritek's traditional high frequency expertise and sub 0.25 micron stepper-based pHEMT high-volume process. These wideband GaAs amplifiers are excellent solutions for external Lithium Niobate modulators.

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High Speed Fiber Optic Products

Model Number	Frequency Range	Pout (+dBm)	Output Voltage (PP) (V)	Asso. Gain (dB)	Data Rate (Gb/s)	Supply Voltage (V)	Supply Current (mA)
CMM3008-AH	30 kHz to 8 GHz	14 (OC-48)	5.0	14	25	5	50
CMM3020-BD	30 kHz to 20 GHz	23 (OC-192)	7.5	10	13	8	250
CMM2030-BD	30 kHz to 30 GHz	18 (OC-192)	5.0	10	13	5	100
CMM3030-BD	30 kHz to 30 GHz	22 (OC-192)	7.0	9	13	8	250
CMM3040-BD	30 kHz to 40 GHz	22 (OC-768)	7.0	8	40	8	300

Power GaAs FETs

Model	Frequency Range	Application	Operation (Volts)	Current (mA)	Gain (dB)	P1dB (dBm)	Noise Figure (dB)	3rd Order Products (dBc)	Package Type
CFK2162-P1	800 - 900 MHz	Base Station/Handset	8	800	20	33	—	30 (@ 29 dBm)	SO-8
CFH2162-P1	800 - 900 MHz	Base Station	10	1100	20	36	—	30 (@ 33 dBm)	Power Flange
CFB0301	0.8 - 2.0 GHz	Base Station/Pole Top/LNA Duplexers	4	70	17	20.5	0.70	58 (@ 5 dBm)	Micro-X
CFB0303	0.8 - 2.0 GHz	Base Station/Pole Top/LNA Duplexers	4	70	19	20.5	0.40	58 (@ 5 dBm)	SO-8
CFK0301	0.8 - 2.0 GHz	Dual Phase/Gain Matched LNA	5	70	16.5	18.5	0.75	58 (@ 5 dBm)	SO-8
CFK2162-P3	1.8 - 2.0 GHz	Base Station/Handset	8	800	14	33	—	30 (@ 29 dBm)	SO-8
CFH2162-P3	1.8 - 2.0 GHz	Base Station	10	1100	14	36	—	30 (@ 33 dBm)	Power Flange
CFK2162-P5	2.3 - 2.5 GHz	Base Station/Handset	8	800	12	33	—	30 (@ 29 dBm)	SO-8
CFH2162-P5	2.3 - 2.5 GHz	Base Station	10	1100	12	36	—	30 (@ 33 dBm)	Power Flange

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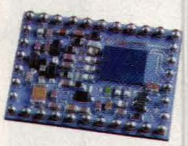

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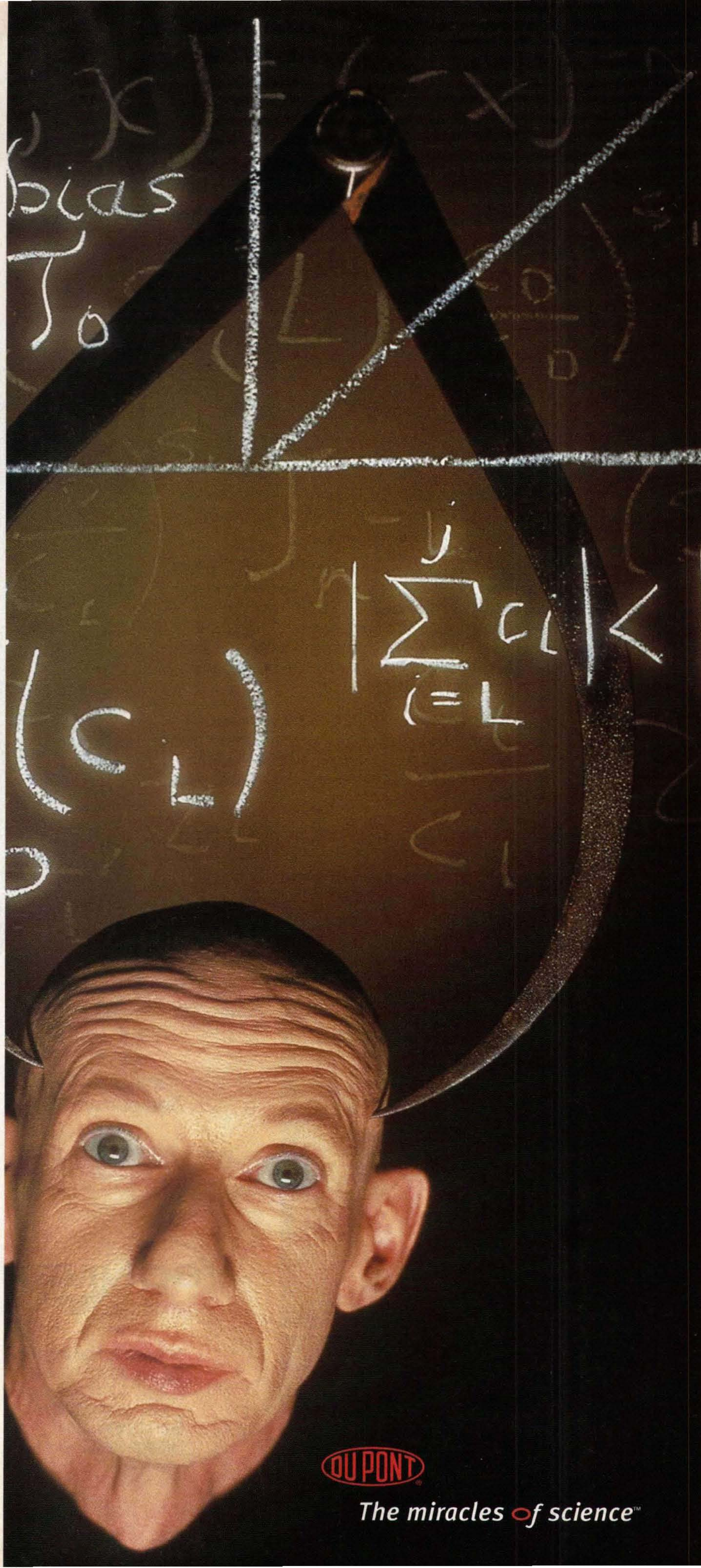

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the limiting amplifier or clock-and-data-recovery (CDR) circuit. The devices also provide output offset control, which supports a degree of flexibility in setting the decision threshold of the limiting amplifier or CDR.

ANADIGICS recently augmented its line of 10-Gb/s TIAs with the addition of the ATA7062 for SONET and dense-wavelength-division-multiple (DWDM) systems. The device features low group delay of 50 ps, optical overload capability to 0 dBm, differential transimpedance of greater than 2 kΩ, sensitivity of −19 dBm, and maximum input current of 550 μA peak-to-peak. The ATA7062 also features DC offset capability. The device, which is based on ANADIGICS's InGaAs heterojunction-bipolar-transistor (HBT) process, is fabricated on 6.0-in. (15.2-cm) substrates. The company's soon-to-be-released model ATA7603 adds to these capabilities by handling optical input power of +3 dBm, which allows it to be used in metro-area-network applications where the erbium-doped fiber amplifier (EDFA) is removed before the Rx stage to reduce cost. This allows an avalanche photodiode (APD) to be used in place of a PIN diode to achieve dynamic range of approximately 30 dB (−27 to +3 dBm).

In addition to its 40-Gb/s InP TIAs, TRW (Redondo Beach, CA) spinoff Velocium (Redondo Beach, CA; www.velocium.com) is using InP to produce the 10-Gb/s model TIA102 TIA, which has 10-pA√Hz current noise density, 1.8-kΩ transimpedance gain, and a 3-dB bandwidth of 11 GHz. The output of the unit is DC coupled with a 0-VDC offset output level. The device has also been integrated with a photodetector in the company's PRX102 module.

Other 10-Gb/s TIAs include:

• Applied Micro Circuits' (San Diego, CA) S3090 TIA has 1.4-kΩ differential transimpedance, 15-pA/√Hz noise-current density, 2.2-mA peak-to-peak maximum input current, voltage-limited outputs to 1400 mV, and adjustable output offset.

• The MAX3970 TIA from Maxim Integrated Products (Sunnyvale, CA), has a transimpedance of 590 Ω, −18-dBm sensitivity, 2-mA peak-to-peak maximum input current, and 150-mW power dissipation from a +3.3-VDC supply. The integrated circuit (IC) also has integrated received signal-strength indication (RSSI).

• The KGA4121D from Oki Electronic Components (Sunnyvale, CA), based on a 0.1-μm gate-length PHEMT process has 60-Ω transimpedance, a 3-dB bandwidth of 9.5 GHz, optical sensitivity of −19 dBm, 18-dB dynamic range, and noise-current density of less than 8 pA√Hz. The device operates from +3.3- and −2.0-VDC sources.

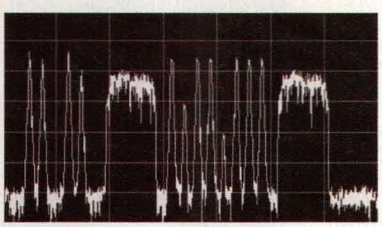
• The TTIA0110G from Agere Systems (Allentown, PA) has a 3-dB bandwidth of 10 GHz, 1-kΩ single-ended transimpedance, input-noise current of 1.5 μA root mean square (RMS), group delay of ±15 ps, and power dissipation of 800 mW. Maximum input current of the amplifier is 1.25 mA peak-to-peak. Its single-ended output swing of 800 mV peak-to-peak supports linear operation with an average input current of up to 360 μA. It has adjustable output offsets as well.

• The GD19906 from Intel (formerly GiGA of Denmark, acquired by Intel in March) is a single-ended device with 500-Ω transimpedance, power dissipation of 750 mW, input equivalent noise current of 12 pA/√Hz, and operation from an +8-VDC source. Intel also offers the LXT14002 transimpedance amplifier, which has 500-Ω single-ended transimpedance, and power dissipation of only 140 mW from a +1.8-VDC source.

• The TGA1180B from Triquint Semiconductor (Hillsboro, OR) was based on a the PHEMT process that has a 11.75-GHz bandwidth, power consumption of 210 mW, transimpedance of 57 Ω, and operation from a +10-VDC supply.

• The HDL6F1241 SiGe TIA from Hitachi Semiconductors (Brisbane, CA) offers power dissipation of 470 mW from a +3.3- and −5.2-VDC source.

As data rates approach 40 Gb/s, the design of optical systems faces chal-



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lenges virtually identical to those encountered by designers of millimeter-wave components and systems. Among those, availability of viable semiconductor compounds, yield, manufacturability, and cost top the list. For these applications, InP is the compound embraced by most manufacturers, thanks to characteristics inherently well-suited for optical systems, including the ability to be integrated with the photodetector (also a III-V compound), excellent carrier-transport characteristics and carrier confinement, and demonstrated cutoff frequencies (f_T) above 150 GHz. The fastest achievable three-terminal devices have all been realized with InP HBTs and HEMTs, which include alloys of InGaAs and indium aluminum arsenide (InAlAs) that can be grown lattice-matched to InP. InGaAs has a higher electron velocity than GaAs which, in part, produces its high cutoff frequency.

InP may indeed be well-suited for optical applications, but it comes with a host of difficulties that have long delayed its commercialization in millimeter-wave systems. Perhaps the most limiting factor has been the lack of high-yielding, large-diameter InP substrates, and the fragility of the material, which have resulted in yields well below those that are acceptable for commercial manufacture. Compared to Si and GaAs, the number of scientists with expertise in InP is very small, which has also hampered its widespread development. As a result, InP has employed principally in military and aerospace systems where its inherent performance advantages outweigh its drawbacks.

However, there has never before been a commercial market opportunity for InP as enormous as the one presented by optical communications. Not surprisingly, the few companies with extensive knowledge of InP, such as Raytheon Co. (Andover, MA) and TRW, have intensified InP development. Their goal is to bring InP into the mainstream electronics marketplace with devices that exploit the inherent properties of the compound, while meeting the requirements for yield and reliability demanded by the merchant market.

The PHEMT, which uses a layer of InGaAs, has long demonstrated its capability at millimeter wavelengths. However, In, which endows the PHEMT with its enhanced transport properties, also causes imperfections that are caused by strain. As a result, channels in the device with In mole fractions greater than approximately 25 percent are not typically fabricated on GaAs substrates. While InP can overcome this limitation because it is lattice-matched with 53-percent mole-fraction InGaAs channels, it has been difficult and expensive to manufacture.

MHEMT Technology

Raytheon has taken an alternate approach, using GaAs-based metamorphic-HEMT (MHEMT) technology. The strain-induced imperfections that are caused by channels with high indium content are eliminated by growing a buffer between the substrate and the active device layers. The buffer absorbs the strain of lattice mismatch and prevents the vertical propagation of dislocation, which maintains the integrity of the active device layers. The result is a device that embodies the inherent advantages of high-speed, low-noise, and low-power dissipation of InP-based HEMTs, with the cost advantage of 4.0- (10.2-) and 6.0-in. (15.2-cm) GaAs wafers.

The approach is used in Raytheon's travelling-wave amplifier **(Fig. 1)** for 40-Gb/s optical systems. Their current design (model RMLA00400) delivers 16-dB gain from 40 Hz to at least 40 GHz, with ripple of ±0.75 dB, noise figure of 2 dB to 35 GHz, and noise-current density of 25 pA√Hz. The device dissipates approximately 450-mW power from a +3.5-VDC supply. Similar to many of the initial companies announcing 40-Gb/s TIAs, Raytheon has many years of experience with InP, delivering InP-based devices to the defense marketplace. Raytheon says that they have been sampling their amplifier for approximately eight months.

Velocium, a company formed in May as an operating company of TRW Space and Electronics to develop high-speed products based on InP and GaAs, has also announced 40-Gb/s TIAs. Velocium is working with InP HBTs and HEMTS in what will ultimately be a complete range of products for optical systems. Similar to Raytheon, TRW's experience with InP was developed to serve military and aerospace applications. "TRW has been working with InP for at least 12 years," says Frank Kropschot, Velocium's director of business development. "Historically, TRW has done a good job of commercializing its technology, and in Velocium we have bundled our core competencies from the space and electronics group to produce solutions [for] emerging markets."

The company's TIAs include the model TIA401 (with differential outputs) and model TIA402 (with single-ended output), which feature 400-Ω transimpedance gain, 20-pA/√Hz current-noise density, and power dissipation of 150 mW from a +4.0- and −6.3-VDC supply for the TIA401, and a +3.8- and −4-VDC supply for the TIA402. In addition to TIAs, Velocium has also announced nearly a dozen other products in its short history, including CDRs, demultiplexers, drivers, and TIAs that are integrated with photodetectors. "Unlike some of our competitors," Kropschot continues, "we have our own fab, with 80 people working in this area, many of whom have been working with InP for at least five years. We also have the world's first InP production line with 4-in. [10.2-cm] wafers."

ANADIGICS, one of the "technology agnostic" fabless enterprises in the optical-device market, has a roadmap that encompasses devices for 10-to-40-Gb/s applications. Although it has developed devices over the years with Si, SiGe, and GaAs, the company is currently concentrating on InP for optical front-end components. Its model ATA7702 40-Gb/s traveling-wave amplifier **(Fig. 2)**, which is being sampled to customers this year, will soon be followed by the model ATA77010, which refines the performance of the earlier device. The ATA7702, based on InP HBT technology, dissipates 200-mW power from a +5-VDC supply, has a transimpedance of 170 Ω, phase deviation of ±1 deg., input-noise current of 25 pA/√Hz, and maximum input current of 6 mW peak-to-peak. The ATA7704 travelling-wave amplifier, currently in development, has a bandwidth of greater than 50 GHz, and target-performance specifications that include 200-mW power dissipation, 180-Ω transimpedance, maximum input-noise current of 25 pA/√Hz, and phase deviation of ±10 deg.

Gtran, Inc., (Newbury Park, CA; www.gtran.com), a company founded in 1999 by semiconductor veterans, including Dr. Frank Lee, formerly of Conexant Systems and GigaBit Logic, introduced its first 40-Gb/s TIA in June. Based on the company's InP HBT, the device has differential outputs, 300-Ω transimpedance, a 45-GHz bandwidth, operates from ±3.3-VDC supplies, and dissipates 150-mW power.

Phillips is using InGaAs for its initial 40-Gb/s products, the first of which (model CGY2140) has transimpedance of 1.4 kΩ, noise-current density of 12 pA/√Hz, and a bandwidth of 45 GHz. The device has a single-ended output and operates from a +5-VDC supply. "We are actively developing InP," says Edwin Dilling, Phillips' international product manager. "Our solution is to deposit InP on a GaAs substrate, which helps solve the fragility problem."

Most analysts concur that the lack of orders for optical components may not sink further, but will instead increase during the second half of 2002 as 10-Gb/s Ethernet is implemented, with SONET infrastructure procurement increasing shortly thereafter. The first 10-Gb/s Ethernet products are only now entering the marketplace, and projections call for rollout during the third and fourth quarters of 2002. The 40-Gb/s systems are still years away, but since the challenges from materials to manufacturing are daunting, intense development will continue and more companies will join the fray. MRF

VCXO targets SONET applications

MODEL VCS22AXT IS a 77.76-MHz, +3.3-VDC VCXO for SONET applications in a 7.5 × 5.0 × 2.0-mm package. The VCXO operates from ±50 through ±100 PPM. Temperature range is −10 to +70°C standard with an optional range of −40 to +85°C. Input current is 50 mA at 77.76 MHz while output symmetry is 40 to 60 percent at 50-percent V_{DD}. The unit uses mesa blank crystal technology and its footprint is approximately 75 percent smaller than standard 14 × 9.6-mm package that is currently in use throughout the telecommunications industry. The devices are available on a 2000-unit tape and reel for automatic assembly systems. P&A: $14.98 (2000 qty.); 10 to 12 weeks ARO.

Fox Electronics, 5570 Enterprise Pkwy., Fort Myers, FL 33905; (888) GET-2-FOX, FAX: (941) 693-1554, e-mail: sales@foxonline.com, Internet: www.foxonline.com.

● Enter No. 60 at www.mwrf.com

Amplifiers offer 20-dB fixed gain

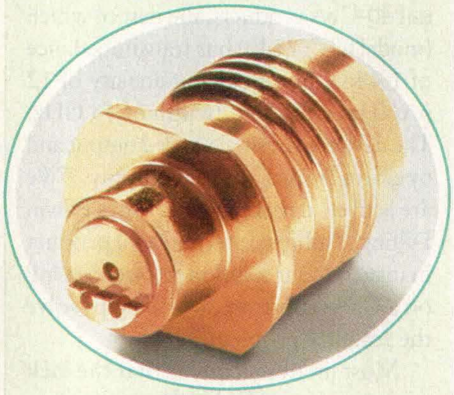
THE AD8353 AND AD8354 are broadband, fixed-gain linear amplifiers that operate at frequencies from 100 MHz to 2.7 GHz. Both units provide a fixed gain of 20 dB with single-ended input and output, internally matched to 50 Ω. The units are specified for operation with a bias voltage of +3 to +5 VDC. The AD8353 provides a linear output power of +8 dBm and an IP3 of +23 dBm while drawing only 42-mA supply current. The AD8354 provides a linear output of +4 dBm along with an IP3 of +19 dBm while drawing only 24-mA supply current. Both devices provide detailed operation at 900 MHz, and 1.9 and 2.7 GHz over the specified operating temperature of −40 to +85°C at +3- and +5-VDC bias voltage. P&A: $1.05 (1000 qty.).

Analog Devices, 1 Technology Way, P.O. Box 9106, Norwood, MA 02062-9106; (800) 262-5643, (781) 329-4700, FAX: (781) 326-8703.

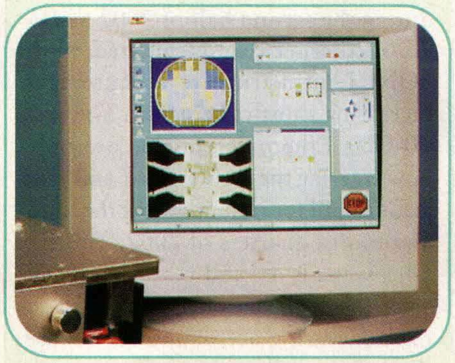
● Enter No. 61 at www.mwrf.com

FOX ELECTRONICS VCXO

ANALOG DEVICES LINEAR AMPLIFIERS



ANRITSU CO. CONNECTORS



CASCADE MICROTECH SOFTWARE

Connectors boast 15-dB return loss

A FAMILY OF V Connectors® uses a design that incorporates the launcher and integrated bead in a single housing, making them suitable for use as the RF input in 40-Gb/s optical modulators. Return loss is 15 dB over the frequency range of DC to 65 GHz, with typical VSWR of 1.3:1 at 65 GHz. The connectors are available in two configurations. Model V115F is a ground-lip version that includes all compensation steps for matching to microstrip or CPW. It provides very short ground path to maintain VSWR at millimeter-wave frequencies. Model V116F is a screw-in version. Both configurations are compatible with existing V Connectors, as well as with 2.4-mm connectors. P&A: $99.00 (unit qty.); 12 to 14 weeks ARO.

Anritsu Co., 1155 East Collins Blvd., Richardson, TX 75081; (800) ANRITSU, (972) 644-1777, FAX: (972) 644-3416, Internet: www.us.anritsu.com.

● Enter No. 62 or at www.mwrf.com

Software calibrates VNA instrumentation

WINCAL 3.0 SOFTWARE automates the steps required for calibrating VNA instruments, reducing calibration time to approximately 45 s. The software offers support for most VNA instruments, including the 8510, 8720, and 8753 from Agilent Technologies and the 360B and 372xxA from Anritsu Co. The software integrates seamlessly with Cascade's wafer-probing stations, which will automatically step between calibration standards. WinCal measures the raw data, computes error coefficients, verifies calibration integrity, and stores error terms in the VNA using LRM, LRRM, SOLT, SOLR, or TRL techniques. WinCal runs on Windows 2000 and NT 4.0, ME, and 98.

Cascade Microtech, Inc., 2430 NW 206th Ave., Beaverton, OR 97006; (800) 550-3279, (503) 601-1000, FAX: (503) 601-1002, e-mail: sales@cmicro.com, Internet: www.cascademicrotech.com.

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Cingular Converting To GSM

A MONUMENTAL deal, approximately worth between $3 and $4 billion, to build a US wireless network based on GSM technology, was struck in December among Cingular Wireless, the number two US service provider, and three of the largest telecommunications equipment manufacturers in the world. The three—European companies Ericsson AB, Nokia, and Siemens AG, will divide up the lion's share of the order, receiving approximately $1.4 to $2 billion, more than $1 billion, and $600 million, respectively. By adopting GSM, Cingular is preparing to compete with US, European, and Japanese rivals to provide 3G services such as data, video, and audio.

The move to GSM represents an important departure for the US wireless industry, since that technology has less than 10 percent of the domestic market. Worldwide, it is the leading wireless technology with particular strength in Europe. Moreover, Cingular is moving toward adopting an international standard that is being used in most countries, but not in the US. A looming question is what effect Cingular's decision will have technically and politically in North America, Japan, and Korea, which lean toward the 1xEV-D0 CDMA air-interface standard for transferring data (GSM is a TDMA-based technology). In the race to offer 3G services, the TDMA and CDMA standards have often squared off against each other, with proponents of each technology engaging in heated debate. These latest events clearly give GSM-based systems the lead in the wireless data market.

Ericsson and Nokia were selected for their ability to supply the GPRS and EDGE system elements that will allow Cingular to offer data services at speeds up to 470 kb/s to mobile users. Users will eventually be able to exchange data with networks in Europe and Asia. Cingular will also switch its voice networks over to GSM as part of the upgrade to EDGE.

According to Nokia, a nationwide rollout of the GSM/EDGE network would start in 2002. Cingular claims that the upgrade will take place in the next 12 to 18 months (from October 2001). MRF

NEW FROM MAURY

QT3.5mm™ Quick Test Connectors & Adapters*

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- Guide Sleeve Design For Automated Applications
- Designed for Long Life

8006E1 No Nut — 8006E11 3/8″ Nut — 8006E21 9/16″ Nut — 8006Q1 Guide Sleeve

ELECTRICAL SPECIFICATIONS

MODEL	FROM	TO	FREQ RANGE (GHz)	VSWR (GHz)
8006E1	QT3.5mm™ (m) with no nut	3.5mm (f)	DC — 26.5**	DC — 16.0, 1.05 16.0 — 26.5, 1.08
8006E11	QT3.5mm™ (m) with 3/8" dia. nut	3.5mm (f)		
8006E21	QT3.5mm™ (m) with 9/16" dia. nut	3.5mm (f)		
8006Q1	QT3.5mm™ (m) with guide sleeve	3.5mm (f)		

**Slightly reduced VSWR specifications to 34 GHz.

REPEATABILITY

REPEATABILITY	DC — 18.0 GHz	18.0 — 26.5 GHz
Push-On Mode	> 45 dB	> 40 dB
Torque Mode	> 50 dB	> 50 dB
Hand Torque	> 50 dB	> 50 dB

Other available configurations include:
- *7mm*
- *TYPE N (f & m)*
- *NMD3.5mm (f)*
- *NMD2.4mm (f)*

ALSO AVAILABLE FROM MAURY

In-Series Precision Adapters

- Low VSWR / Low Loss
- DC to 50 GHz
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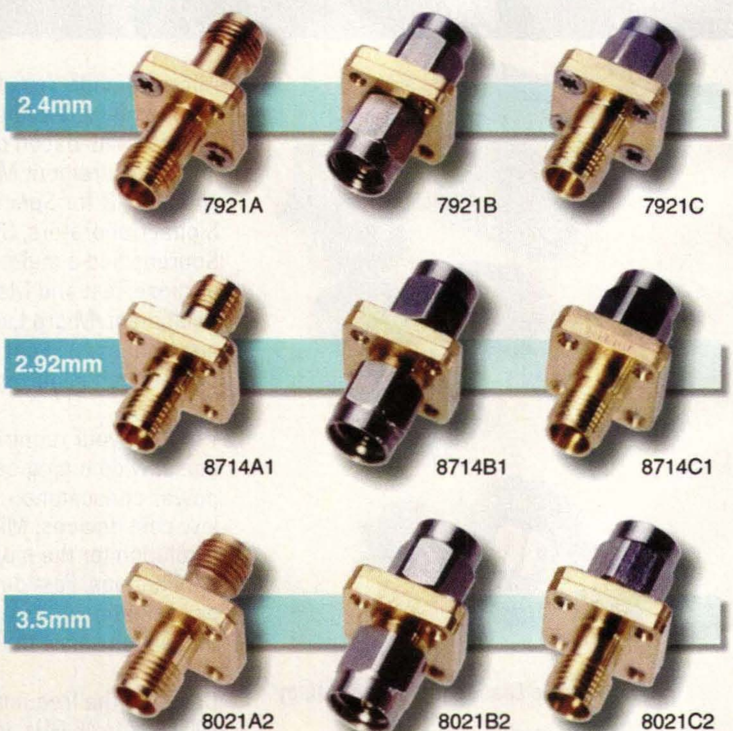
- Phase Matched / Minimum Length
- Bulk Head & Panel Mount Configurations Available
- Between-Series Adapters Are Also Available



ELECTRICAL SPECIFICATIONS

MODEL	FROM	TO	FREQ RANGE & MAX. VSWR
7921A	2.4mm Q (f)	2.4mm Q (f)	DC — 26.5 GHz, 1.06 26.5 — 40.0 GHz, 1.10 26.5 — 34.0 GHz, 1.15
7921B	2.4mm Q (f)	2.4mm Q (m)	
7921C	2.4mm Q (f)	2.4mm Q (m)	
8714A1	2.92mm K (f)	2.92mm K (f)	DC — 4.0 GHz, 1.05 4.0 — 20.0 GHz, 1.08 20.0 — 40.0 GHz, 1.12
8714B1	2.92mm K (m)	2.92mm K (m)	
8714C1	2.92mm K (f)	2.92mm K (m)	
8021A2	3.5mm (f)	3.5mm (f)	DC — 18.0 GHz, 1.05 18.0 — 26.5 GHz, 1.08 26.5 — 34.0 GHz, 1.12
8021B2	3.5mm (m)	3.5mm (m)	
8021C2	3.5mm (f)	3.5mm (m)	

Between-Series configurations include:
- ***2.4mm to 2.92mm (K)***
- ***2.4mm to 3.5mm***

* U.S. PATENT #6210221

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CONTRACTS

AR/Kalmus—Has signed a contract with the Department of the Army for the purchase of 49 of its model M512-20 RF PAs. The amplifiers are valued at $396,000.

Andrew Corp.—Has completed the supply, installation, and commissioning of the FreedomIP™ Broadband VSAT network for Philcomsat (Philippine Communications Satellite Corp.). The $3 million project was completed during the summer and provides direct Internet access to the Philippines' Internet Service Providers (ISPs) and corporate clients. Current clients on the new network include the Catholic Bishops Conference of the Philippines, Angelnet, Cybernet, the Far Eastern University, and the University of the East.

Motorola's Global Telecom Solutions Sector (GTSS)—Announced that it has been awarded another $34.8 million contract by China United Communications Corp. (China Unicom) to expand the operator's 800-MHz CDMA network in China's Hebei Province. Under the terms of the contract, Motorola's GTSS will deliver its CDMA solution to China Unicom, including SC4812T™ base stations, base-station controllers, and mobile switching centers. The expansion project was carried out in four cities in Hebei Province—Handan, Cangzhou, Hengshui, and Xingtai.

Spectrum Signal Processing, Inc.—Will receive $500,000 (Canadian currency) in funding from the Defence Industrial Research Program (DIRP) to create additional capability for its flexComm SDR product line.

Radiant Networks, Inc. and Nsight Teleservices—Signed an agreement to commercially deploy within Nsight's franchise area during 2002. Established as the Northeast Telephone Co. in 1910, Nsight today offers local, long-distance, Internet, mobile, and other telecommunications services throughout the Midwest.

FRESH STARTS

Microwave Development Laboratories—Has appointed Sea-Port Technical Sales of Bellevue, WA to be its exclusive representative for the Pacific Northwest region.

Mericom Corp.—Has moved into its new corporate headquarters in the Irvine Spectrum Corporate Business Center in Irvine, CA. The company had been located in Lake Forest, CA. The new headquarters in Irvine is located at the junction of Interstates 5 and 405 and is twice as large as Mericom's previous facility. The 32,580-sq.-ft. complex combines warehouse and office space. Mericom is the building's sole occupant. The company's new address is 167 Technology Dr., Irvine, CA 92618. The phone number is (949) 265-4200.

ITS Networks, Inc.—Signed actress Melanie Griffith to endorse their products. Also, signed an agreement with El Corte Ingles, a Spain-based retailer and department store chain, to distribute the ITS line of "Melanie" calling cards.

SaRonix—Opened their new Eastern Development Center (EDC), a design and development facility located in State College, PA, within the Innovation Park at Pennsylvania State University. The EDC will focus upon the creation of value-added frequency- and and timing-control products catering to the requirements of next-generation broadband-communications and optical-transmission applications.

Gould Fiber Optics—Announced their strategic partnership with Seikoh Giken, an international manufacturer of optical connectors and interconnects for the fiber-optic industry.

TRAK Communications, Inc.—Merged TRAK Microwave Corp. and their sister subsidiary TRAK Microwave Ltd. (aka TRAK Europe). Although the merger did not affect the manufacturing facility locations in Tampa, FL and Dundee, Scotland, the merger has realigned the sales and engineering groups. The realignment consists of four strategic business units (SBUs) headed by Vito Parato, president of TRAK Microwave.

Stratos Lightwave—Announced the opening of its new Northwest Technology Center. The center's goal is the exploration and development of advanced technologies, subsystems, and products for high-end fiber-optic communications. Located just outside of Seattle, WA, this center will conduct research and development (R&D) aimed at creating fiber-optic products, provide custom tailoring of existing Stratos fiber-optic products for customers, and act as Stratos Lightwave's West Coast customer interface for these custom products. The center is also expected to play a role in the various committees developing standards for fiber-optic systems and components.

Vitesse Semiconductor Corp. and Nu Horizons Electronics Corp.—Announced an agreement under which Nu Horizons will become the exclusive distributor of Vitesse's line of chip-set solutions for communication equipment manufacturers. This agreement, which became effective on October 1, encompasses selling rights for North America.

Cardinal Components—Revealed its partnership with PGI Industries, a division of JACO Electronics, Inc., a worldwide distributor of electronic components. JACO/PGI Electronics has been selected by Cardinal as a strategic international distributor partner for its expanding family of timing products.

Motient Corp. and TMI Communications and Co., L.P.—Announced that their new joint venture, Mobile Satellite Ventures, L.P. (MSV) has been granted the necessary regulatory approvals from the FCC and its Canadian counterpart, Industry Canada. These regulatory approvals have allowed MSV to complete the previously announced combination of Motient's satellite operations with those of TMI Communications and to become a stand-alone entity.

Gabriel Electronics, Inc.—Appointed WaveLink Associates as its representative in the southeastern US. MRF


SMITH

Racal Appoints Smith To Military-Aerospace VP Spot

Racal Instruments has appointed TERRY SMITH as vice president of the Military-Aerospace Test Group, based in San Antonio, TX. Mr. Smith's previous position was program manager and director of Automatic Test Systems for CACI (Sunset Resources).

Sabritec—MIKE KHAVAR to quality assurance manager; formerly senior customer quality manager at Robertshaw Controls Co.

Silicon Labs—DANIEL ARTUSI to COO; formerly corporate vice president and general manager of the Networking and Computing Systems Group at Motorola's Semiconductor Products Sector.

Amicore—JIM FITZSIMMONS to president and CEO; formerly senior vice president of corporate planning with the PaineWebber Group.

Kyocera Wireless Corp.—HOWARD W. "SKIP" SPEAKS, JR. to president and COO; formerly CEO of Triton Network Systems.

X-ident—PETER J. KUZMA to president of US operations; formerly employed by Proctor & Gamble.

TRAK Communications, Inc.—RALPH L. PHILLIPS to president of TECOM Industries in Chatswoth, CA; formerly vice president of business development of the Integrated Systems Division at Northrup Grumman. Also, ROBERT A. (TONY) GRIMES to president of TRAK Microwave; formerly president of Pinkerton, Inc.

Excell Agent Services (EAS)—JOHN ANDREWS to executive vice president of sales and marketing; formerly president of MicroAge Teleservices.

TransEDA—BOB QUINN to the board of directors; remains as president of Network Virtual Systems, Inc.

alterna Technologies Group, Inc.—MICHAEL HINES to vice president of marketing; formerly strategic planning and marketing officer at Client-Logic Corp.

TDK Semiconductor Corp.—MICHAEL HENDERSON to director of strategic marketing for the Broadband Communications Group; formerly division director for business and technology planning at Mindspeed Technologies, Inc.

Mericom Corp.—MARK KELSO to manager of the Central West region; formerly chief technology officer and vice president of technical operations for Northcoast Communications. Also, DON DOHRMAN to vice president and general manager of the North Central region; formerly director of construction and and vice president of business development for Labarge Clayco Wireless. In addition, PAUL ANUSZKIEWICZ to vice president and general manager of the Southeast region; formerly vice president of network operations for Powertel, Inc.

Seiko Instruments USA, Inc. Fiber Optics Group—FRANK J. CAPPARELL to production manager for the North American Fiber Optic Cable Assemblies production facility in Torrance, CA; formerly project manager in the Value Base Six Sigma Group at ITT Cannon.

Schaffner—MUHAMAD NAZARUDIN to the position of product manager; formerly applications engineer at Voltach Instruments. MRF


CAPPARELL


NAZARUDIN

▸ SHORT COURSES

Mobile Communications and Wireless Networks
February 12-15, 2002 (Reston, VA)
Learning Tree International
Reston, VA 20190-5630
(800) 843-8733, FAX: (800) 709-6405
Internet: www.learningtree.com

Digital Signal Processing: Principles and Applications
February 13-14, 2002 (Redwood City, CA)
University of California–Berkeley Extension
Continuing Education in Engineering
Berkeley, CA 94720-7010
(510) 642-4111, FAX: (510) 642-0374
Internet: www.unex.berkeley.edu/enroll

Using the GSM Digital Wireless Interface
February 19-22, 2002 (Madison, WI)
Dept. of Engineering Professional Development
University of Wisconsin–Madison
Madison, WI 53706
Jen Oster
(800) 462-0876, FAX: (608) 263-3160
e-mail: custserv@epd.engr.wisc.edu
Internet: http://epdweb.engr.wisc.edu

Satellite RF Communications and Onboard Processing
March 5-7, 2002 (Cleveland, OH)
Applied Technology Institute
Clarksville, MD 21029
(888) 501-2100, FAX: (410) 531-1013
e-mail: info@ATIcourses.com
Internet: www.ATIcourses.com

Commercial High-Performance Computing Conference
March 19-20, 2002 (Hyatt Orlando, Orlando, FL)
Intermedia Group and Illuminata
Marilyn Crafts
e-mail: mcrafts@imgevents.com
Internet: www.imgevents.com/highperformance

▸MEETINGS

International Solid State Circuits Society (ISSCC 2002)
February 4-6, 2002 (San Francisco Marriott Hotel, San Francisco, CA)
The Solid State Circuits Society of the IEEE
Piscataway, NJ 08855-1331
Internet: www.isscc.org

6th International Commercialization of Military and Space Electronics & Exhibition
February 11-14, 2002 (Los Angeles Airport Marriott Hotel, Los Angeles, CA)
Components Technology Institute, Inc.
Huntsville, AL 35801
Dale L. Stamps
(256) 536-1304, FAX: (256) 539-8477
e-mail: dale@cti-us.com
Internet: www.cti-us.com

SUPERCOMM ASIA 2002
February 20-22, 2002 (New Delhi, India)
Interads Ltd.
Lisle, IL 60532
Lynn Lochow, Dir., International Sales and Marketing
(630) 271-8210, FAX: (630) 271-8234
e-mail: llochow@showmgmtservices.com

ICAPS 2002 International Conference on Advanced Packaging and Systems
March 10-13, 2002 (Reno Hilton Hotel, Reno, NV)
International Microelectronics and Packaging Society (IMAPS)
Tim Lenihan
e-mail: TimLenihan@imaps.org
Internet: www.imaps.org.

Embedded Systems Conference San Francisco
March 12-16, 2002 (Moscone Center, San Francisco, CA)
CMP Media LLC
(415) 278-5260, FAX: (415) 278-5390
e-mail: esc@cmp.com
Internet: www.embedded.com/esc.

CTIA Wireless 2002
March 18-20, 2002 (Orlando, FL)
Cellular Telecommunications & Internet Association
(800) 421-6338, FAX: (415) 979-2250
Internet: www.ctiashow.com

RF & Hyper Europe 2002
March 26-28, 2002 (Paris Expo Exhibition Center, Porte de Versailles, France)
BIRP
17, avenue Ledru-Rollin
Paris 75012 France
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e-mail: birp@birp.fr
Internet: www.birp.com

2002 International Conference on Compound Semiconductor Manufacturing Technology (GaAs MANTECH)
April 8-11, 2002 (Sheraton San Diego Hotel and Marina, San Diego, CA)
International Conference on GaAs Manufacturing Technology
c/o Lucky Gold Co.
4126 Crescent Dr.
St Louis, MO 63129
e-mail: info@GaAsMantech.org
Internet: www.gaasmantech.org

2002 International Reliability Physics Symposium
April 8-11, 2002 (Hyatt Regency Dallas, Dallas, TX)
Electron Devices Society and Reliability Society of the IEEE
William R. Tonti, General Chair
IBM Microelectronics
Essex Junction, VT 05452
e-mail: wtonti@us.ibm.com
Registration:
(315) 339-3968, FAX: (315) 336-9134
e-mail: pub_services@irps.org

Novel Patch Antenna Feeds 3G IMT-2000 Mobile Handsets

GROWTH IN THE 3G digital cellular system standard adopted by the ITU, the IMT-2000 standard, has been slowed this past year due to poor economic conditions. Growth is expected in 2002 and beyond, keyed by the availability of lower-cost components, such as a novel microstrip patch antenna developed by Ya Jun Wang and associates from the Nanyang Technological University (Nanyang, Singapore). By introducing a single shorting pin and a thin rectangular slot perforated in a square patch measuring 34 × 34 mm, the probe-fed antenna can realize an impedance bandwidth of 25.6 percent (with better than 10-dB return loss) with the dual-frequency operation over the IMT-2000 band of 1885 to 2200 MHz. (The antenna features two adjacent resonant frequencies at 1.92 and 2.31 GHz.)

The square patch has thickness of 11 mm for ruggedness. A rectangular slot of 25 × 2 mm is perforated parallel to the Y-axis and is kept away from the X-axis by 9 mm. A shorting pin of 2-mm radius and a probe feed of 0.6-mm radius are located on each side of the thin slot. For more information on the slotted patch antenna, see "A Novel Microstrip Patch Antenna for 3G IMT-2000 Mobile Handsets," *Microwave and Optical Technology Letters,* December 20, 2001, Vol. 31, No. 6, pp. 488-491.

ILO Offers Enhanced Locking Range

ILOS ARE USEFUL signal sources for microwave and millimeter-wave frequencies, although they are limited in locking range. Fortunately, Youngsang Jun and associates from the Telecom Examination Division of the Korean Intellectual Property Office (Taejon, Korea) have developed a new design approach for ILOs that features an enhanced locking range. A key to increase the locking range is the design of frequency doublers using the impedance substitution method, which allows oscillators to be designed as amplifiers, viewing the oscillator signals as input signals to the amplifiers with the same output and input powers. For more information, see "A New Design Approach For An Injection-Locked Oscillator With An Enhanced Locking Range," *Microwave and Optical Technology Letters,* December 5, 2001, Vol. 31, No. 5, pp. 325-327.

Self-Heterodyne Approach Sends Millimeter-Wave TV Signals

MILLIMETER-WAVE FREQUENCIES have long entranced design engineers with potential wide-bandwidth transmissions. Unfortunately, millimeter-wave components tend to be expensive due to the tiny geometries at such small wavelengths. Key components, such as low-phase-noise oscillators, have simply not been available in support of practical millimeter-wave Tx and Rx designs for consumer applications, such as TV broadcasting. However, in an attempt to overcome the limitations of millimeter-wave component manufacturing, Yozo Shoji and fellow researchers from the Communications Research Laboratory, Ministry of Posts and Telecommunications (Tokyo, Japan) have developed a unique self-heterodyne Tx/Rx system for low-cost terrestrial digital television broadcasting at 60 GHz using 64-state QAM on a COFDM format. The system provides a BER of 10^{-6} without any FEC.

Designed for household use, the 60-GHz system can distribute digital terrestrial, satellite, and CATV signals throughout the house without wires. In addition to sending a modulated signal, the Tx also sends an LO signal used in the upconversion. The Rx reuses this LO signal to perform downconversion of the received modulated signal. Using this method, the phase noise and frequency offsets of the LO are removed, and the Rx can operate without an LO of its own. The experimental system operates at a center frequency of 60.2 GHz with an LO frequency of 58 GHz. The Rx features noise figure of 5 to 6 dB with 30-dBi antenna gain.

A terrestrial digital broadcasting signal was created with a test-signal generator and first upconverted to 635 MHz, which corresponds to channel 40 in the Japanese UHF television band. The researchers chose one of several digital signal formats (64QAM on OFDM carriers) available according to the Japanese digital TV-signal standard, choosing the format that was most sensitive to frequency offsets and phase noise. The TV signal was next upconverted to a center frequency of 2.2 GHz, and fed to the Tx, which then upconverted the signal to 60.2 GHz.

The Rx downconverts the 60-GHz signal to an IF signal by square-law detection with a diode mixer. The IF signal is further downconverted to a center frequency of 37.15 MHz and send to a demodulator. For more information on the novel millimeter-wave system, see "60 GHz Band 64QAM/OFDM Terrestrial Digital Broadcasting Signal Transmission by Using Millimeter-Wave Self-Heterodyne System," *IEEE Transactions On Broadcasting,* September 2001, Vol. 47, No. 3, pp. 218-227.

DESIGN

Understand Bluetooth Protocol Testing

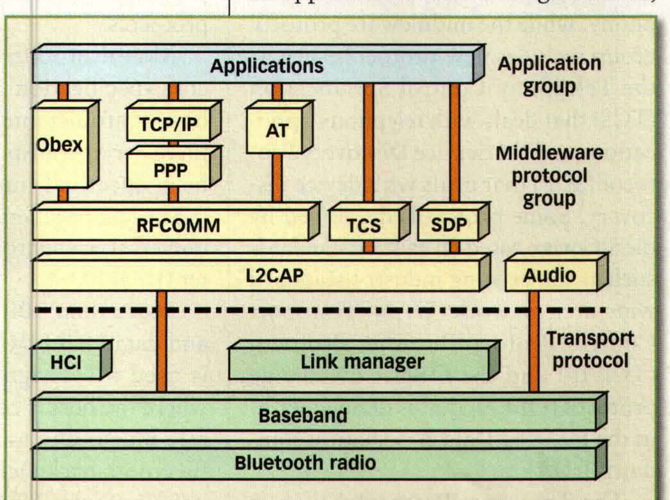
A significant part of preparing a product for Bluetooth qualification involves the development of Bluetooth protocols and performing hardware/software integration.

Bluetooth protocol analysis ensures that wireless connections are made reliably and that supported applications run smoothly. Despite the details provided in the published Bluetooth specifications (available at www.bluetooth.com), implementation details and choice of development and debug tools are left to the developer. By reviewing the Bluetooth protocols and the prequalification testing procedures, it may be possible to simplify the selection of protocol analysis tools.

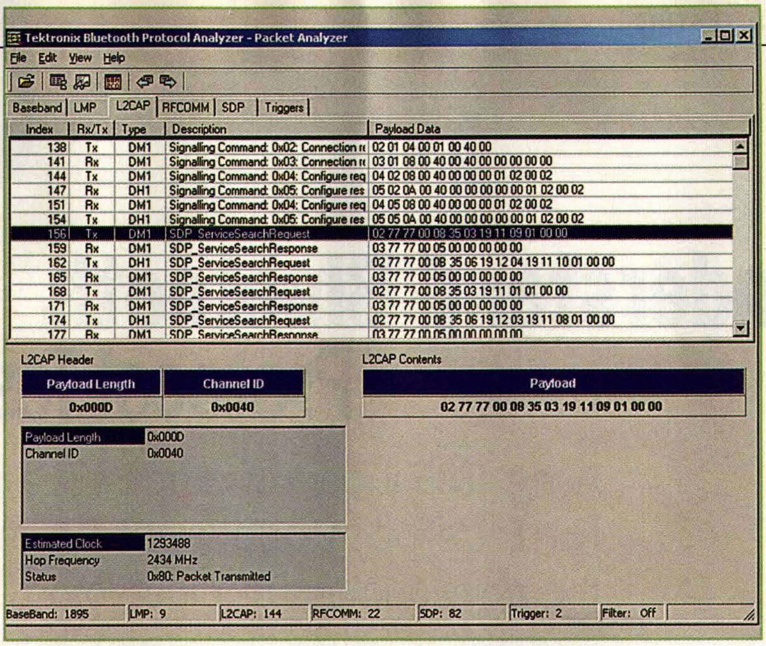
DR. GEOFF LAWDAY
Tektronix Reader in Measurement
Buckinghamshire Chilterns University College, Buckinghamshire, England; e-mail: geoff.lawday@bcuc.ac.uk.

The Bluetooth Special Interest Group (SIG) includes promoter businesses 3Com, Agere Systems, Ericsson, IBM, Intel, Lucent, Microsoft, Motorola, Nokia, and Toshiba, with more than 2000 Adopter/Associate member companies. Nominal Bluetooth operation is at 2.4 GHz with 0-dBm transmit power for an approximate indoor range of 10 m, although a higher-power class of Bluetooth operation supports a range up to 100 m using transmit power of +20 dBm.

Bluetooth devices that are within range of each other can establish connections on an ad-hoc basis where they can form, disconnect, and reform connections without user intervention. Two or more Bluetooth devices that establish a connection and form a small wireless network are known as a piconet. The raw data rate of 1 Mb/s supports three duplex voice channels at 64 kb/s or an asymmetric link of 723.2 kb/s in the sender direction that permits 57.6 kb/s in return from the receiver (Rx). Alternatively, a 432.6-kb/s symmetric link can be established. In a piconet, one Bluetooth device acts as a master and controls all of the traffic in the piconet while all other devices act as slaves. The master is defined as the device that initiates the connection procedure to establish a piconet. Only one master exists per piconet and the smallest piconet consists of only two devices (in a point-to-point configuration): one master and one slave. Up to seven slaves can be active in a piconet (in a point-to-multipoint configuration). Devices



1. The Bluetooth protocol stack consists of several layers of protocols, including transport, middleware, and application protocols.



2. This display screen was taken from a Bluetooth protocol analyzer from Tektronix.

can be placed in a "park" mode and a master can support up to 255 of these devices. The User Discovery Service (UDS) can be used by a new device to determine what network services are available from the various connected devices.

A group of piconets with overlapping areas of coverage is known as a scatternet. Each piconet is identified by a different frequency-hopping sequence. A Bluetooth device may participate in different piconets, provided that it is only active in one piconet at a time. A device can act as a slave in different piconets, but as a master in only a single piconet. For interpiconet communication, a device selects the proper master identity and clock offset to synchronize with the channel of the desired piconet.

A radio-hopping sequence of 1600 hops/s, which provides a hop duration of 625 µs, is used to combat interference and fading while adding to the security of the link. The hopping sequence is determined by the address of the piconet master and the timing is determined by the master unit's system clock. As part of the connection process, a slave will receive timing information from the master, including the master's current clock and hopping sequence. This ensures that all Bluetooth devices in a piconet are synchronized.

In the implementation of a Bluetooth module, the radio and link controller are developed in the hardware, whereas the link manager is based in the firmware. The radio and the link controller, along with the baseband functions, were the first parts of the Bluetooth specification to mature. At present, the radio is generally a separate chip from the Link Controller/Link Manager although, for space- and power-conscious designs, the goal of most manufacturers is to provide a single-chip, low-cost solution. Other approaches make use of a host processor and firmware to implement baseband functionality, keeping the radio separate. Regardless of the hardware/software implementation, the Bluetooth protocol stack **(Fig. 1)** and hierarchy are maintained.

The application group of protocols is composed of the actual applications that use Bluetooth links. Some legacy applications may be unaware of the Bluetooth transports, such as a modem dialer or web-browsing client.

The Middleware Protocol Group acts as the intermediary between the user applications and the transport group. Their primary purpose is to deliver different broad classes of messaging to the Logical Link Control and Adaptation Protocol (L2CAP) layer. RFCOMM deals with legacy or existing serial protocols such as the advanced-technology (AT) command-based telephony, while the middleware protocol group includes new protocols such as the Telephony Control Specification (TCS) that deals with telephony applications and the Service Discovery Protocol (SDP) that deals with device discovery. Some protocols developed by the SIG were based on existing standards such as the existing industry-standard wide-area network (WAN) Transport Control Protocol/Internet Protocol (TCP/IP) and the OBject EXchange protocol (OBEX) that is defined within the Infrared Data Association standard (IrDA).

The Transport Protocol Group is composed of the protocols designed to allow Bluetooth devices to locate each other, establish connections and exchange data and/or voice traffic, as well as interface to the upper-level protocols.

The link controller is basically the hardware controller for the radio and host to the baseband-protocol functions. It is responsible for determining what data to transmit and when, what data to wait for and when, which carrier frequency to transmit, and which power to use. Baseband functions basically include piconet and device-control functions such as connection creation, frequency-hopping sequence selection and timing, modes of operation such as power control and secure operation, and medium-access functions such as polling, packet types, packet processing, and asynchronous-connectionless (ACL) and synchronous-connection-oriented (SCO) link types. These processes, along with others that are not mentioned, basically execute the baseband protocol. All higher-level packets are broken down into baseband packet data units (PDUs) for efficient transmission across the air. The channel timing of Bluetooth is not sufficient to support the long packet lengths that are produced by some of the higher-level protocols.

More than 300 pages in the Bluetooth core specification are devoted to the host-controller interface (HCI), where three serial transport protocols have been specified: universal serial bus (USB), standard serial link RS-232, and universal asynchronous Rx/transmitter (UART).

More than 100 command, event, and data HCI PDUs are defined. HCI is used for design implementations where the host is connected to a separate Bluetooth module. Examples are Bluetooth backpacks for personal digital assistants (PDAs) or cell phones.

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S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	±0.60
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Implementers who wish to build Bluetooth directly into their designs with tight integration may eliminate the HCI, but they must still provide a test-control interface (TCI) for compliance testing. Current development kits use HCI as a command and control interface and execute HCI commands from a personal computer (PC).

The L2CAP supports higher-level protocol multiplexing, packet segmentation and reassembly (SAR), and conveys quality-of-service (QoS) information between applications. It also creates channels between applications in two different devices with identified addresses or endpoints known as channel identifiers (CIDs). Note that the Link Manager is responsible for setting up and maintaining physical links between devices and the L2CAP layer creates the channel connection between applications using the ACL link. While the Baseband defines two link types (ACL and SCO), L2CAP is defined for ACL only. Two types of CIDs are defined: connection-oriented (device to device) and connectionless (broadcast) CIDs.

L2CAP must support protocol multiplexing since the Baseband does not support a "type" field to identify the higher-layer protocol that is being multiplexed above it. L2CAP must be able to route received packets to the appropriate protocol above it—RFCOMM, SDP, and TCS. L2CAP permits higher-level protocols to transmit and receive data packets up to 64 kb without knowledge of the lower layers. Bluetooth baseband packets are limited in size to a maximum transmission unit (MTU) of 341 B. Large L2CAP packets must be segmented into multiple smaller baseband packets prior to transmission.

Serial interfaces are ubiquitous in computing and telecommunications where devices such as notebook computers, PDAs, digital cameras, and IR communications systems normally have or make use of serial-communication ports. These devices are seen as archetypical embedded Bluetooth applications. RFCOMM provides a standard RS-232C serial protocol to consolidate the different serial-communication configurations into a single format before passing them to L2CAP. RFCOMM is similar to wired serial protocols that require a specially configured cable such as an RS-232C lead that connects to a serial-communication port and RFCOMM is often referred to as the "Cable Replacement Protocol." One of the key benefits of RFCOMM is that software developers can make use of the many legacy software applications that make calls to serial ports with little or no modifications. The RFCOMM layer provides a virtual COM port to these serial applications with framing, multiplexing, and the normal serial characteristics such as:

- Modem status—request to send/clear to send (RTS/CTS), data set ready/data terminal ready (DSR/DTR), data carrier direct (DCD), ring.
- Remote line status—break, overrun, parity check.
- Remote port settings—baud rate, parity, number of data bits, etc.
- Parameter negotiation—frame size.

The emergence of information appliances and the requirement for self-discovery of available services without user intervention has led to the development of the crucial SDP. This contrasts with wired services such as a local-area network (LAN), where a network administrator manages the normally static network resources and services that are available to the users. Service discovery is a process that allows Bluetooth clients to locate and gather information, as well as make use of services on other Bluetooth-enabled servers (devices) in a piconet.

A server can be any Bluetooth device offering a service that can be used by another Bluetooth device, and a client can be any device wanting to use a service. Each SDP server maintains a data base of information that a client needs when accessing a service. To use SDP, an L2CAP channel must be established between the SDP client and server. The services provided by Bluetooth have universally unique identifiers (UUIDs) assigned by the Bluetooth standard, although implementers can create their own UUIDs, since the specification is designed to remove UUID duplication.

The Bluetooth TCS defines how telephone calls should be sent across a Bluetooth link. It provides guidelines for the signaling needed to set up point-to-point and point-to-multipoint calls. It also provides a way to send dual-tone-multifrequency (DTMF) tones across a Bluetooth link. TCS is adapted from ITU-T Recommendation Q.931. It should be noted that the acronym used for telephony control does not fit in with the convention used in the rest of the Bluetooth stack. By following the rest of the stack naming conventions, this should be called TCP, however, it was decided that this would conflict with the Internet TCP.

The test and qualification processes for a Bluetooth product are rigorous. Product developers are dependent on specialized tools such as a Bluetooth protocol analyzer. A protocol analyzer, such as the BPA100 Bluetooth Protocol Analyzer from Tektronix (Beaverton, OR), can provide a real-time trace of packet transfers and decode the packets to reveal the integrity of a design **(Fig. 2)**.

Tools such as a Bluetooth protocol tester and a spectrum analyzer are typically used by Bluetooth Qualification Test Facilities (BQTFs). However, a Bluetooth protocol analyzer is approximately one-tenth the cost (typical) of a full Bluetooth protocol test system. The protocol analyzer is generally used for device development, debugging, and prequalification testing. A Bluetooth protocol analyzer is particularly useful in the test and debug phase of hardware/software integration.

An analyzer may typically act in a piconet device as either the master or slave to interact with other devices. However, devices that work with the analyzer could fail to work with each other. Ideally, the analyzer will also be nonintrusive and act as a piconet "sniffer," detecting and detailing Bluetooth traffic independent of the piconet under test. A particularly important feature of the high-end analyzers is their ability to generate predetermined error packets

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to enable the test and debug of the error-correction functions of the higher levels in the protocol stack.

Advanced protocol analysis is based on the capture and inspection of specific packets or events, which is enabled through the use of complex analyzer trigger functions and deep real-time trace buffers. Isolating bugs in the L2CAP, RFCOMM, and SDP layers requires the logging, decoding, and effective display of baseband packets. Moreover, it is unlikely that the developer will be a Bluetooth expert, since the wireless link is typically an adjunct to their product. Therefore, the analyzer must have an intuitive human interface to enable the developer to concentrate on their product and implement Bluetooth with ease.

The qualification process ensures that Bluetooth products comply with the Bluetooth specification, thereby enabling interoperability between devices. Bluetooth qualification is a necessary precondition of the intellectual-property license for Bluetooth wireless technology. Qualification is also necessary to apply a Bluetooth trademark to a product. Qualification is not type approval; manufacturers of Bluetooth products must also go through the normal procedures of regulatory type approval in each country or region where they want to sell the product.

Several administrative bodies are involved in the qualification of a Bluetooth product:

• The Bluetooth Qualification Review Board (BQRB) consists of delegates from each Bluetooth promoter whose main task is making policy.

• The Bluetooth Qualification Administrator (BQA) is responsible for administering the Bluetooth Qualification Program on behalf of the BQRB.

• The BQTF is any test facility that is accredited by the BQRB to test Bluetooth products.

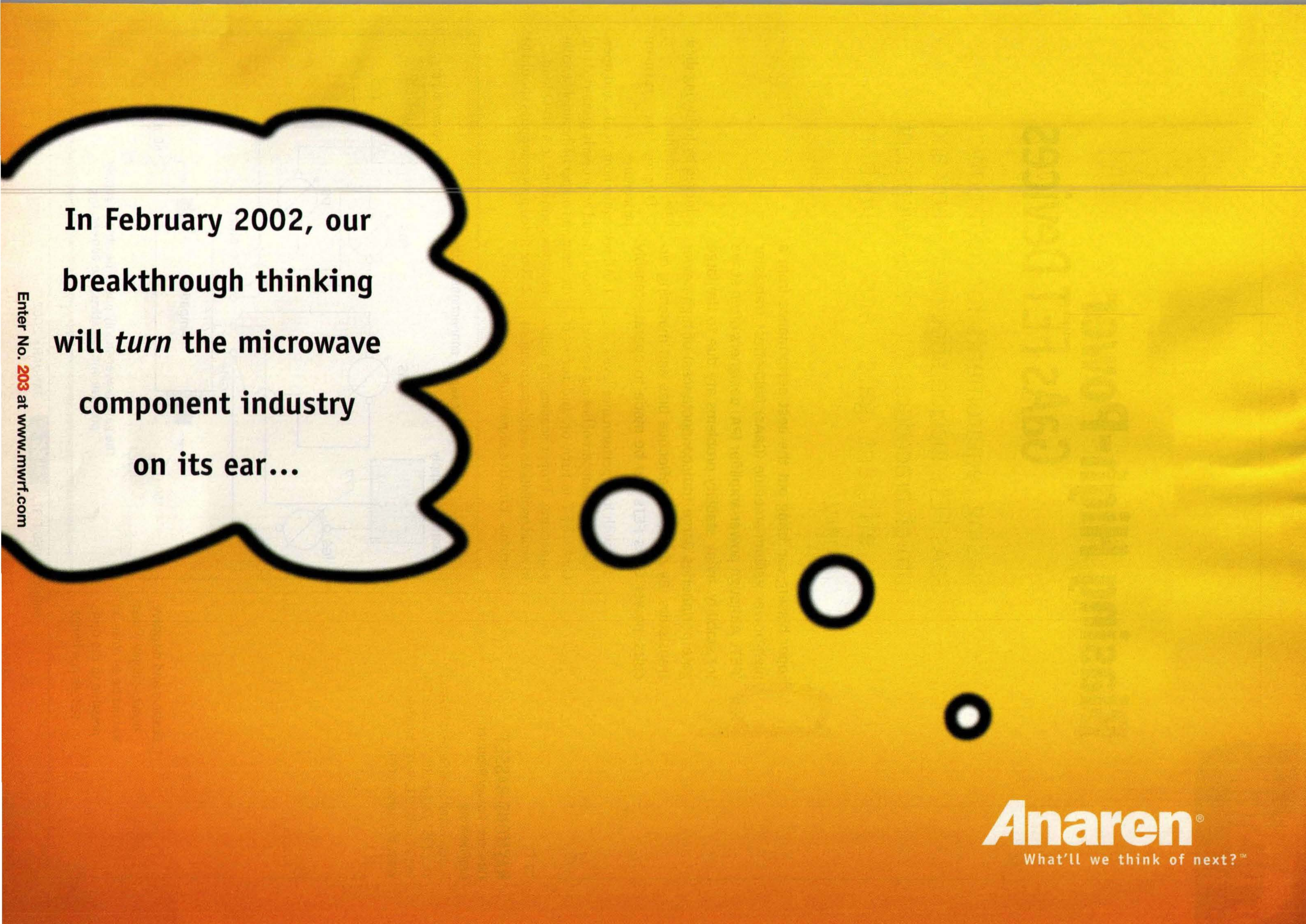
• The Bluetooth Qualification Body (BQB) is a person authorized by the BQRB to provide services to an adopter seeking the Bluetooth product qualification. They are responsible for checking declarations and documents against requirements, reviewing product test reports, and listing products to the official data base of Bluetooth qualified products.

• The Bluetooth Technical Advisory Board (BTAB) is a forum consisting of all BQBs and BQTFs, responsible for advising the BQRB on technical matters relating to test requirements, test cases, test specifications, and test equipment. MRF

FOR FURTHER READING

Brent A. Miller and Chatschik Bisdikian, *Bluetooth Revealed,* Prentice Hall, Englewood Cliffs, NJ, 2001.

Jennifer Bray and Charles F. Sturman, *Bluetooth—Connect Without Wires,* Prentice Hall, Englewood Cliffs, NJ, 2001.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Biasing High-Power GaAs FET Devices

Biasing requirements for high-power GaAs FETs include effective turn-on and turn-off procedures and the development of efficient gate- and drain-bias circuitry.

Proper biasing can bring out the best performance from a high-power gallium-arsenide (GaAs) field-effect transistor (FET). Although power-amplifier (PA) designers often strive for stability, many stability problems are due to the large gate peripheries (large transconductances) of high-power transistors. By designing effective bias and matching circuits, power GaAs FETs can be made to operate reliably and with high performance levels.

An important part of biasing a power GaAs FET is turn-on and turn-off sequencing. Proper sequencing helps to avoid oscillations and device transient burnout. Effective sequencing can be achieved by following these basic guidelines.

During the turn-on procedure:

1. All test equipment, tools, and operators should be properly grounded and the input and output of the amplifier connections connected to a 50-Ω load.
2. Regulated power supplies should be used.

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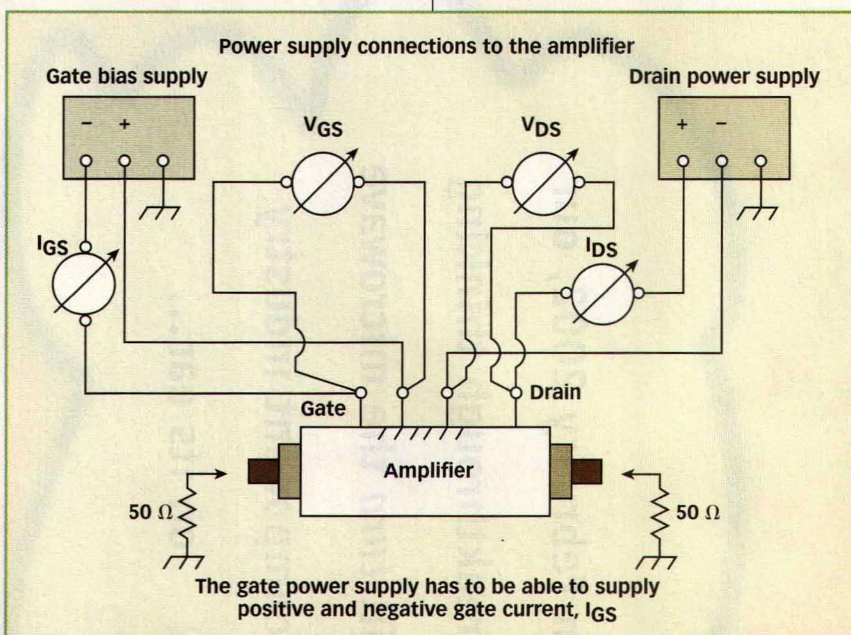


1. Positive and negative power-supply wires should be as close as possible to the GaAs FET device flange.

3. Adequate voltage-spike protection should be used on both bias lines.
4. Once the first three steps are followed, 0 VDC can be applied on the gate (V_{gs}) and 0 VDC on the drain (V_{ds}).
5. Then, the gate voltage should be decreased to the minimum device pinchoff voltage, usually −4.0 to −0.5 VDC.
6. The drain voltage is then slowly increased to the value recommended by the device manufacturer, approximately +10 to +12 VDC typical.
7. The gate voltage is then increased to reach the quiescent drain current suggested by the device manufacturer.
8. Finally, the RF drive signal can be applied.

During the turn-off procedure:

1. The RF drive signal should first be turned off.
2. The gate voltage should be decreased to the minimum device pinchoff voltage.
3. The drain voltage should be decreased to 0 VDC.
4. Finally, the gate voltage should be increased to 0 VDC.

Power GaAs transistors are unstable at low drain voltages, which is why the device is in pinchoff condition when the drain voltage is lower than the recommended operating drain-voltage value (typically +10 to +12 VDC).

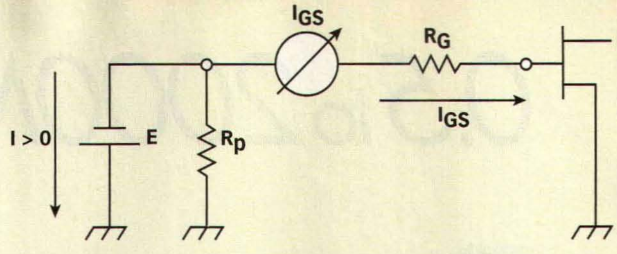
Due to the large transconductance of high-power devices, drain-to-gate coupling should be minimized. This coupling can result from the wires used to connect a device to its power supplies and to the ammeters and voltmeters used in the measurements.

The wires connecting the amplifier ground to the positive gate power-supply terminal and to the negative drain power-supply terminal should be independent (separate wires). Both wires should be connected as close as possible to the device flange **(Fig. 1)**. Drain and gate wires should be as far from each other as possible to minimize coupling. A better solution is to use shielded cables and ground these cables (shielding, positive gate, and negative drain wires) only at the ground close to the device.

The internal resistance of the ammeters in the gate- and drain-bias circuits

should be as low as possible (even if Kelvin probes are used to measure the gate and drain voltages). As an example, the value of the gate resistance in series with the gate has a recommended value, R_g. The total value of the resistance seen from the device gate should be this recommended value. If an ammeter with an internal resistance of R_a is used, the resistance R_c connected in series in the gate-bias circuit should be $R_g - R_a$, assuming that the internal resistance of the power supply is very small.

Use of standard power supplies for the gate bias



E: Gate power supply that cannot supply positive I_{GS}

$R_P < -V_P\ MAX/2I_{GS}\ MAX$ $P > 2 - (V_P\ MIN)^2/R_P$

2. A resistor in parallel to the terminals of the gate power supply ensures a positive gate current for gate voltages below −0.05 VDC.

With low drive level, the gate current (I_{gs}) is negative and has a low absolute value. Under large drive conditions, the gate current is positive with a relatively large value (up to 300 mA for large devices). As a result, the gate power supply must be able to supply positive and negative current. Since standard laboratory power supplies cannot supply positive current, resistance R_p must be connected in parallel to the gate power-supply terminals **(Fig. 2)**. To ensure that the internal current (I) in the power supply will flow from the negative to the positive terminal, R_p should be:

$R_p < (-V_{pmax})/(2I_{gsmax})$

where:

V_{pmax} = the maximum pinchoff voltage, and

I_{gsmax} = the maximum gate current under normal drive conditions.

A conservative assumption is that the highest gate voltage where the device may operate is one-half the maximum pinchoff voltage. In these calculations, V_p is negative and I_{gs} is positive. As an example, with a model FLL1500IU-2C GaAs FET from Fujitsu Compound Semiconductor (San Jose, CA), V_{pmax} = −0.1 VDC. If I_{gsmax} = 60 mA for a particular application, then:

$R_p < 0.1/(2 \times 0.060) = 0.8\ \Omega$

The power rating (P_r) of R_p should be:

$P_r > (V_{pmin})^2/R_p$

where:

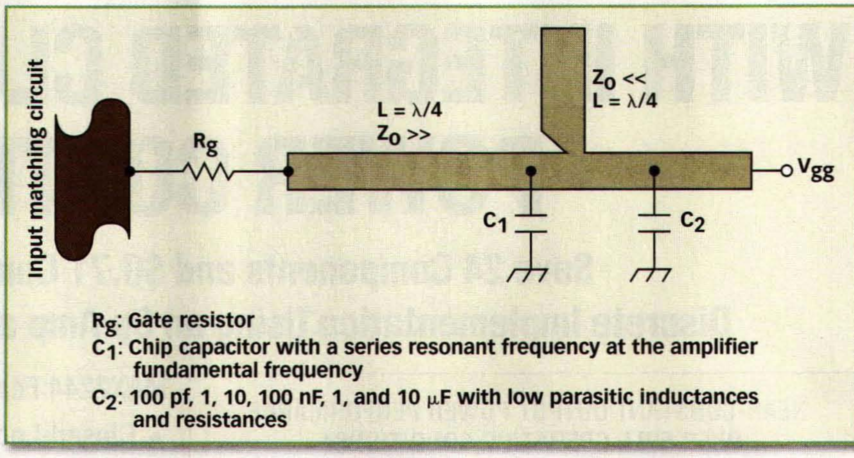
V_{pmin} = the minimum pinchoff voltage of the device.

Since V_{gs} can be lower than V_{pmin}, a resistance with at least a power double of this minimum power should be used.

For this example with the FLL1500IU-2C, and with $Rp < 0.8\ \Omega$ and $V_{pmin} = -0.5$ VDC, the resistor power should be:

$P_r > (0.5)^2/0.8 = 0.3$ W

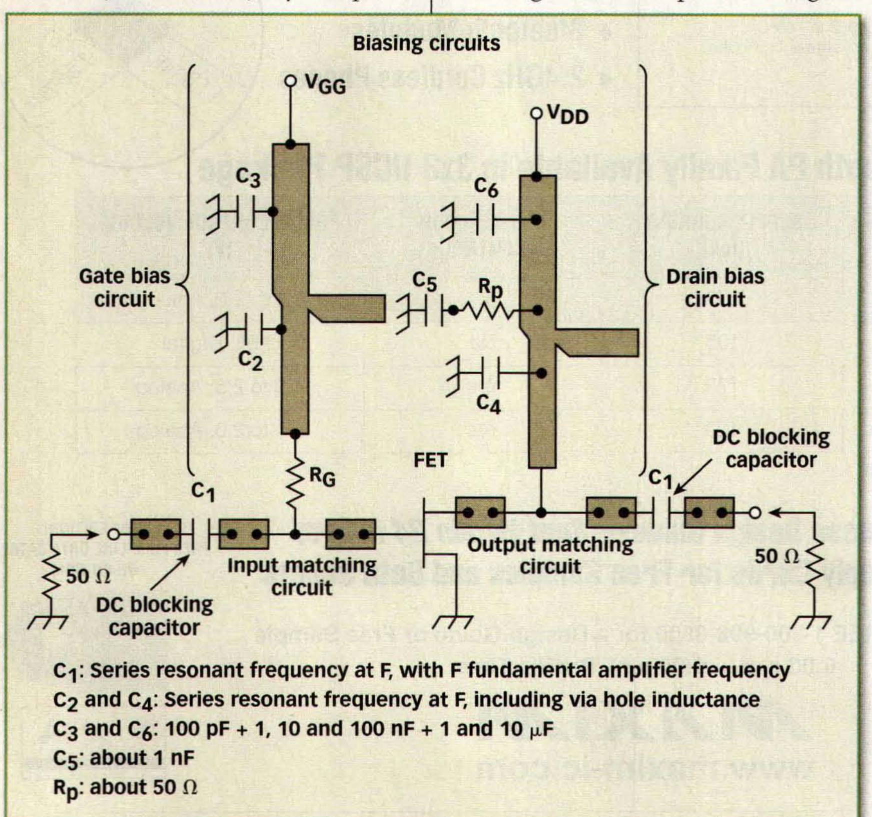
A 1-W, 0.7-Ω resistor connected in parallel to the terminals of the gate power supply will ensure that a positive gate current can be supplied to 60 mA for any gate voltage less than −0.05 VDC.



4. When the gate-bias circuitry is not required to also provide matching, this circuit can be used.

The gate-biasing circuit has several functions. It should maintain a constant gate-to-source voltage (V_{gs}). It should be able to supply negative and positive gate current. It should protect the gate by limiting the gate current when the device goes into breakdown (drain-to-gate or gate-to-source) condition or when the gate-to-source junction is biased with a positive voltage. These abnormal operating conditions for the devices can be due to an operator error, an overdrive, a system problem, or electrostatic discharge (ESD). The gate-biasing circuit should also stabilize the device in case a negative resistance appears in the gate at any frequency where the device has positive gain. It should also filter the desired signal, the spurious products, and the harmonics generated by the device input port from low to high frequencies without affecting the device input-matching circuitry. The gate-biasing circuit should also isolate the gate from any signal coming from the drain through the bias circuits.

A generic amplifier with input- and output-matching and gate- and drain-bias circuits is shown in **Fig. 3. Figure 4** shows a circuit used when the biasing circuit has no matching function. In this latter case, the gate resistance is placed as close as possible to the device gate for better protection against ESD and oscillation. The impedance of this circuit in parallel to the input-matching circuit is infinite at the fundamental frequency (assuming the circuit losses are low). The characteristic impedance of the first short-circuited quarter-wavelength line can be relatively large since the gate current is low. **Figure 5** shows a biasing circuit used as a parallel short-circuited stub for matching purposes. It presents an impedance of $jZ_o\tan\theta$ (assuming that the losses are low) connected in parallel to the input-matching circuit. In this case, R_g cannot be connected between the input-matching circuit and the bias circuit. It is connected between the extremity of the first microstrip line and capacitor C2. For the protection of the gate, resistor R_g should be connected before capacitor C2. Capacitor C1 is small, since it resonates at the fundamental frequency (including the viahole inductance to the ground); it cannot store too much energy and has high impedance for the low frequencies. For low frequencies, if a negative resistance appears in the



3. This generic amplifier block diagram includes the gate- and drain-bias circuits as well as input- and output-matching circuits.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gate, it will be in series with R_g and the total resistance value should be positive. Capacitor C1 is not needed when a low-impedance, open-circuited quarter-wavelength line is used, since the line-input impedance is null at the fundamental frequency.

For good low-frequency stability, the gate resistance should be connected as close to the gate as possible. At these frequencies, the DC-blocking capacitor is an open circuit, the decoupling capacitors are short circuits, and the quarter-wavelength line has a very short electrical length. If a negative resistance ($R < 0$) appears in the gate and the sum of the resistances is positive ($R + R_g > 0$), the device will be stable. This requires R_g to have a sufficient value and the connection to the ground to be short at low frequencies. Connecting R_g close to the gate reduces the connection length to the ground.

The gate-current limitation under breakdown, positive voltage, large drive, and ESD conditions requires a value of R_g that is sufficient, albeit limited for the following reasons. The gate voltage should be kept constant versus drive level. The gate current versus drive level can change from a negative value to approximately 300 mA for the largest devices. To limit variations, the maximum value of R_g must be limited by:

> **The maximum value of R_g required to avoid thermal runaway is defined experimentally and is fortunately higher than the value already defined.**

$R_{gmax} = \Delta V_{gs} / \Delta I_{gsmax}$

where:

$\Delta V_{gs} < 0$

$\Delta I_{gs} = I_{gsmax} - I_{gsmin}$.

Since $-I_{gsmin}$ is very small:

$\Delta I_{gs} = I_{gsmax}$

For a model FLL1500IU-2C, I_{gsmax} = 60 mA at compression. For a desirable limit of $\Delta V_{gs} = -0.15$ VDC, the maximum gate resistance is:

$R_{gmax} = 0.15/0.060 = 2.5\ \Omega$

The maximum value of R_g is also limited by device thermal runaway. The runaway mechanism can be explained as: $V_{gs} = V_{gg} - I_{gs}R_g$. I_{gs} is negative without RF drive. When the temperature rises, I_{gs} decreases and V_{gs} increases. This rise in V_{gs} increases the drain current I_{ds}, which increases the power dissipated in the device (and the channel temperature). The rise in chan-

nel temperature results in a decrease in I_{gs}, a consequent increase in I_{ds}, and so on. The maximum value of R_g required to avoid thermal runaway is defined experimentally and is fortunately higher than the value already defined.

The value of the resistance that should experience the device gate is provided in the device data sheet. This resistance is known as R_g but it may be different than the resistance directly connected in the gate-biasing circuit, since other resistances may be involved.

If the value of R_g cannot be found, the following formula for GaAs FETs with V_{ds} from +9 to +12 VDC can be applied:

$R_g = 400/P_{sat}$

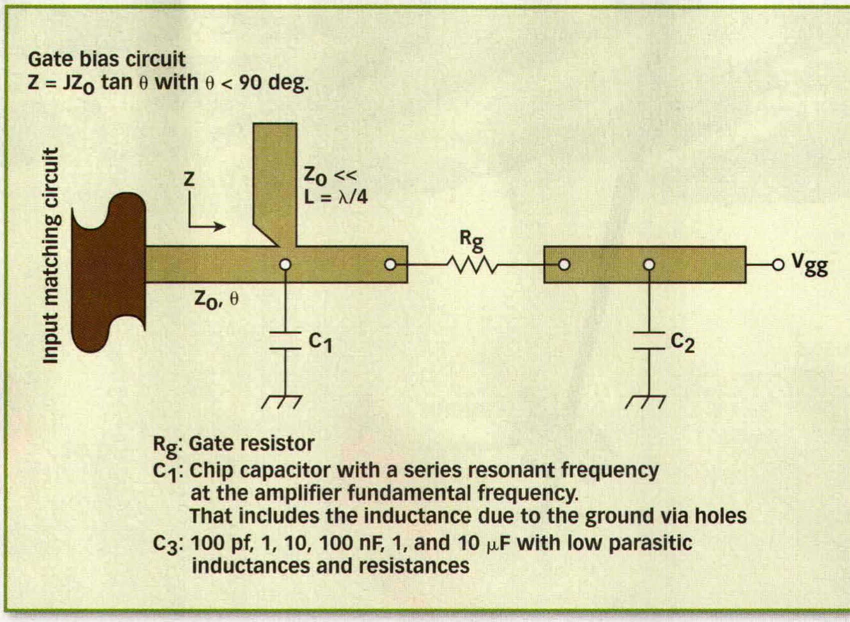
where:

R_g = the gate resistance (in ohms) and

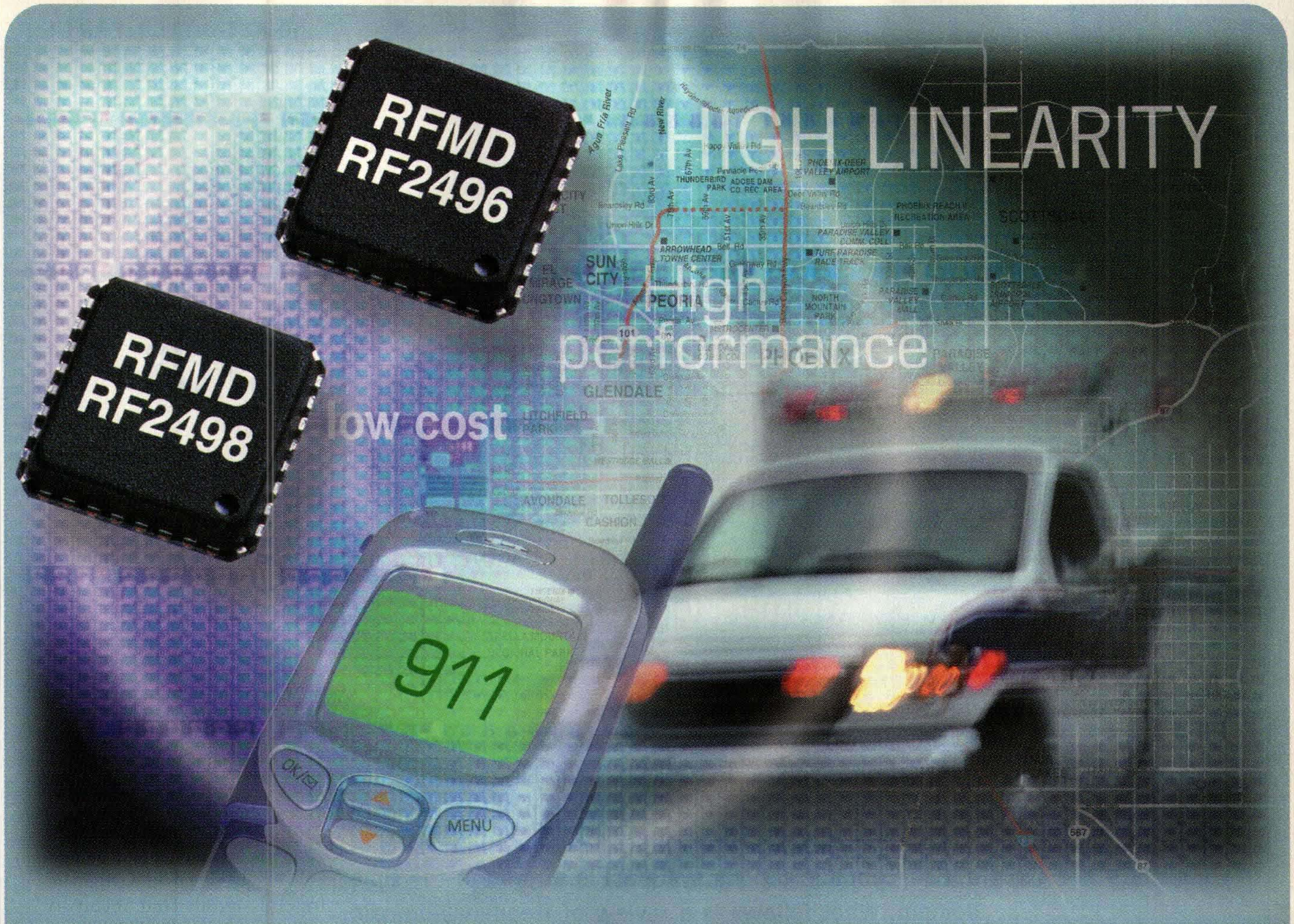
P_{sat} = the saturated output power (in watts).

For push-pull devices, this resistance is the equivalent resistance in each gate and the output saturated power is the power of each side of the device.

Part 2 of this article will explain the techniques for proper drain-bias design and discuss the various types of DC blocking elements used in PA design. MRF



5. This circuit combines input matching with the gate-bias circuitry.



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Noise Figure (dB)*	2.4	2.1 (Cell)/2.2 (PCS)	1.9 (Cell)/2.2 (PCS)	2.0/1.8 (Cell)/2.1 (PCS)/1.8 (GPS)
IIP3 (dBm)	+9 (LNA)	+11 (Cell LNA) +8 (PCS LNA)	-9.0 (Cell)/-8.5 (PCS) Cascaded results for RX path	+11 (Cell LNA)/+8 (PCS LNA)/ +3 (GPS LNA)
Package	4x4mm LCC	5x5mm LCC	8x8mm module	5x5mm LCC
Technology	SiGe HBT	SiGe HBT	SiGe HBT	SiGe HBT
Application	Cell CDMA AMPS	Cell/PCS CDMA AMPS	Cell/PCS CDMA AMPS	Cell/PCS CDMA AMPS GPS

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Gauge Phase Jitter And Noise In VCXOs

By understanding the stability of crystal oscillators in terms of jitter, meaningful specifications can be applied to time-domain (digital) communications systems.

Oscillator specifiers often refer to instabilities or noise in terms of phase noise. This may be useful in the frequency domain, but in terms of jitter, a more practical view of source stability (especially for oscillators used in digital or optical-communications systems) is offered in the time domain. What follows is a review of frequency-domain oscillator noise and a rundown on analysis and measurement techniques for studying oscillator jitter in the time domain.

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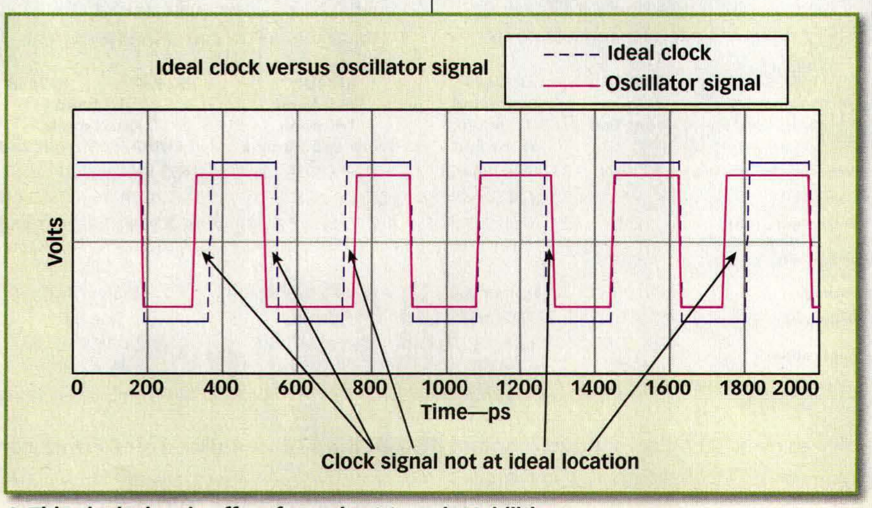
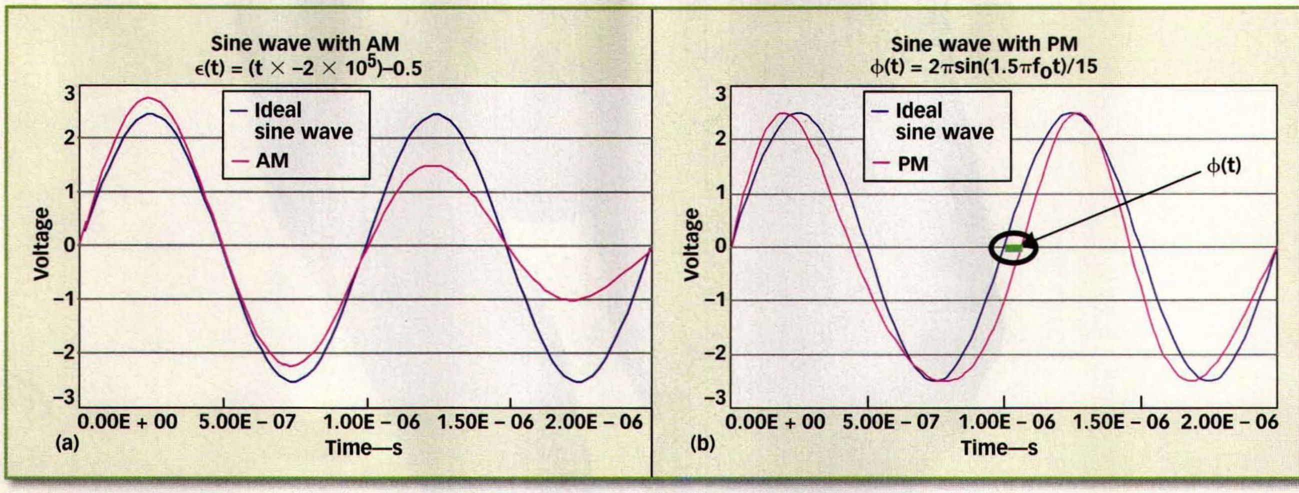
Short-term frequency instabilities, experienced in the time domain as jitter, can cause problems in analog and digital signals. As system operating frequencies have increased, these instabilities have gained increasing importance, because their relative size to the total period length is larger. The instabilities can eventually cause slips or missed signals that result in loss of data. **Figure 1** shows a square wave with jitter compared to a suitable signal at the same long-term frequency.

Since all frequency-control devices have some short-term instability, it is necessary to have quantifiable measures. Phase noise, Allan variance, phase jitter, wander, time-interval error, cycle-to-cycle jitter, period jitter, root mean square (RMS) versus peak-to-peak versus 1σ, and bandwidth-limited jitter are all terms



1. This clock signal suffers from short-term instabilities.



2. This plot compares a suitable sine wave with an AM signal (a) for the signal shown on the right (b).

used for the characterization of short-term frequency instabilities. This article discusses three time-domain measurement techniques, and two frequency-domain measurement techniques. Through these discussions, the difference between bandwidth-limited jitter and unspecified bandwidth measurements will be illustrated.

To understand the characterizations, perhaps the easiest approach is to discuss instabilities for a sine wave in the time domain, and then extend the discussion to square waves and the frequency domain.

A suitable sinusoidal voltage source can be characterized by:

$$V(t) = V_p \ \sin(2\pi f_o t) \qquad (1)$$

where:

V_p = the peak amplitude and

f_o = the nominal frequency of the oscillator.

A sinusoidal signal that varies from −2.5 to +2.5 VDC with a nominal frequency of 1 MHz would have the form of:

$$V(t) = 2.5 \sin\left[2\pi\left(1 \times 10^6 t\right)\right] \qquad (2)$$

Noise in the signal can be broken down into two separate attributes:

1. Peak values of the signal vary in time, which is amplitude-modulation (AM) noise.
2. The point at which the signal crosses a reference voltage varies from its suitable location, which is part of a phenomenon known as phase-modulation (PM) noise or frequency-modulation (FM) noise. This latter attribute characterizes the short-term frequency instabilities of a source.

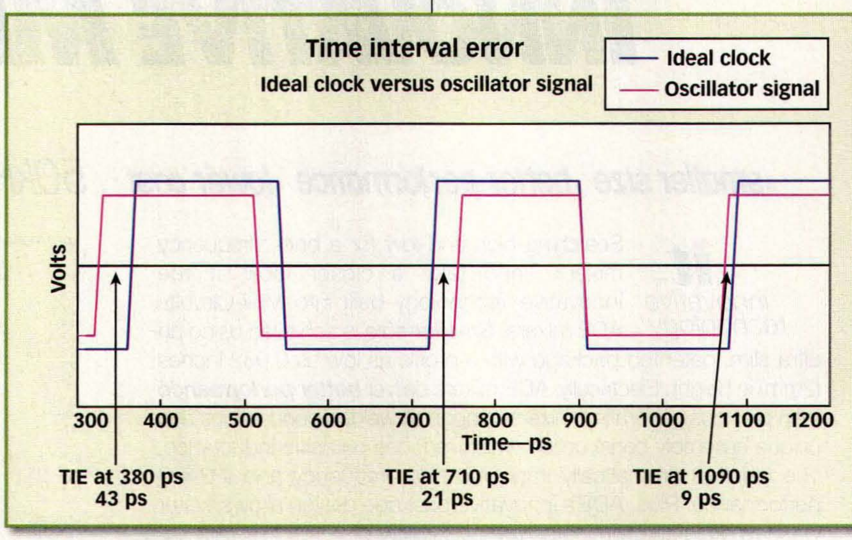
The two noise-source types can be modeled by:

$$V(t) = V_p(\left[1 + \varepsilon(t)\right] \sin \left[2\pi f_o t + \phi(t)\right]) \qquad (3)$$

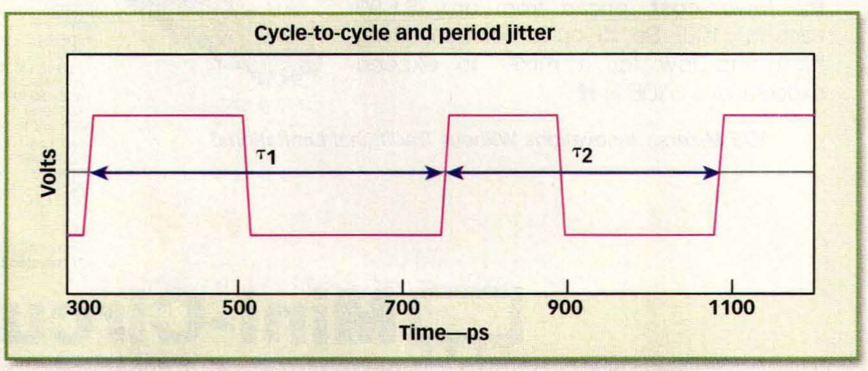
where:

$\epsilon(t)$ = the amplitude-modulation noise, and

$\phi(t)$ = the PM noise.



3. TIE is a measure of φ(t) that compares a jittery clock to an ideal clock source.



4. Adjacent cycles of a clock are used to calculate cycle-to-cycle jitter.

Both are modeled as time-dependent quantities. **Figure 2a** shows the effects of amplitude noise modulation for the signal in **Fig. 2b**. For this example, $\epsilon(t) = t(-2 \times 10^5) - 0.5$. Parameter $\epsilon(t)$ is typically an insignificant source of noise for voltage-controlled crystal oscillators (VCXOs) with square-wave outputs and will be ignored in this article.

For the example of PM noise in Fig. 2b, $\phi(t) = 2\phi\sin(1.5f_o t)/15$. For square-wave VCXO noise characterization, $\phi(t)$ is the dominant noise source, and typically of most concern for telecommunications and digital applications.

The units of measure for $\phi(t)$ are as follows. For the sample above, the value of $\phi(t)$ is 80 ns measured at the end of the first cycle at the positive rising 0-VDC reference level. The unit interval (UI) is a measure of the ratio of $\phi(t)$ to the period of oscillation. For this example, it would be 0.08 UI in terms of radians. To determine the radian value, the formula $2\pi \times$ UI should be used. For this example, the value would be 0.502 rad. The radian value for $\phi(t)$ is in appropriate units for use in Eq. 1.

Unlike the example of Fig. 2, $\phi(t)$ is typically random in nature. However, different mechanisms of an oscillator will have specific effects on the spectral content of $\phi(t)$. These mechanisms will not be discussed here, but are covered in the application note "Frequency Stability in the Time Domain" [written by Mike Wacker and available on the Corning Frequency Control, Inc. (Mount Holly Springs, PA) website at www.corningfrequency.com].

Telecommunications applications are typically concerned with the spectral content of $S_\phi(t)$ [expressed as the spectral density $S_\phi(f)$] or some representation of it, which can be measured through a phase-noise test system. (For a description of the spectral content of noise, see Appendix A in the full-length version of this article available on the *Microwaves & RF* website at www.mwrf.com). For many digital applications, with larger $\phi(t)$ tolerances (on the order of 10 ps or greater), the time-domain measurement and representation of $\phi(t)$ suffices. The mechanics of accurate measurements, and the formulas involved can become lengthy. This article focuses on qualitative discussion of the methods, and graphical representations of the results.

Time-domain analysis of $\phi(t)$ is the easiest to perform and visualize. The time-domain technique discussed in this application note is performed with a digital oscilloscope.[1] In the Direct RAMBUS Clock Generator Validation Specification, digital oscilloscopes are specified for jitter analysis. While this standard

is widely used in the computer industry, it has limited use in the telecommunications industry since the bandwidth of $\phi(t)$ is not well-defined. There are several different types of measurements that can be taken with this configuration.

Time-interval error (TIE) is a measure of $\phi(t)$ that compares a jittery clock to an suitable clock source operating at the long-term average frequency of the signal **(Fig. 3)**. To measure TIE, as well as any other time-domain method, a reference level and edge of the waveform must be specified. TIE is measured by subtracting the time of crossing through the reference level by the clock from the suitable crossing location. If a reference level is not defined, a 0-VDC rising edge (for an AC-coupled signal) is assumed.

Cycle-to-cycle jitter compares the difference in the period length of adjacent cycles. This would be calculated by subtracting period τ_1 from period τ_2 in the example shown in **Fig. 4**. Again, the reference level and edge to measure must be specified.

Period jitter compares the length of each period to the average (τ_{ave}) period of a suitable clock at the long-term average frequency of the signal. Each datapoint would be generated by subtracting $\tau_n - \tau_{ave}$
where:

τ_n is the period being measured. (Note: For complete details on the test equipment used in this article, please contact the author by e-mail at dchandler@ofc.com.)

When taking the three measurements, the reference level for the reading will have an impact on the results. The reference level specifies the point of each waveform to compare. Typically it is specified by the voltage level along the rising or falling edge. **Figure 5** shows the difference in values obtained by changing the reference level from 0-VDC positive edge to −145-mV negative edge on a 155.52-MHz, +3.3-VDC, low-voltage-positive-emitter-coupled-logic (LVPECL) VCXO. The two traces in Fig. 5 show a 29-ps difference in value when the jitter reading was taken at a different point on the waveform.

To provide descriptive statistics for all of the previous readings (time-interval error, cycle to cycle, period) data sets for several adjacent cycles are collected. The peak-to-peak value and standard deviation (1τ), or RMS, are then calculated from these data points (for sinusoidal signals the RMS value and standard deviation are approximately equal).

To obtain meaningful results using a digital oscilloscope, a system should have the following capabilities:

1. High sampling rate (8 GSamples/s or greater).

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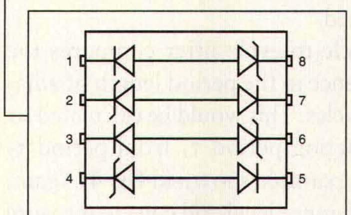

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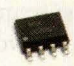

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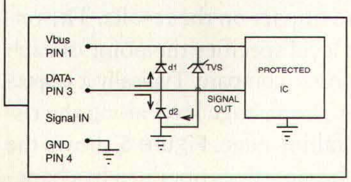

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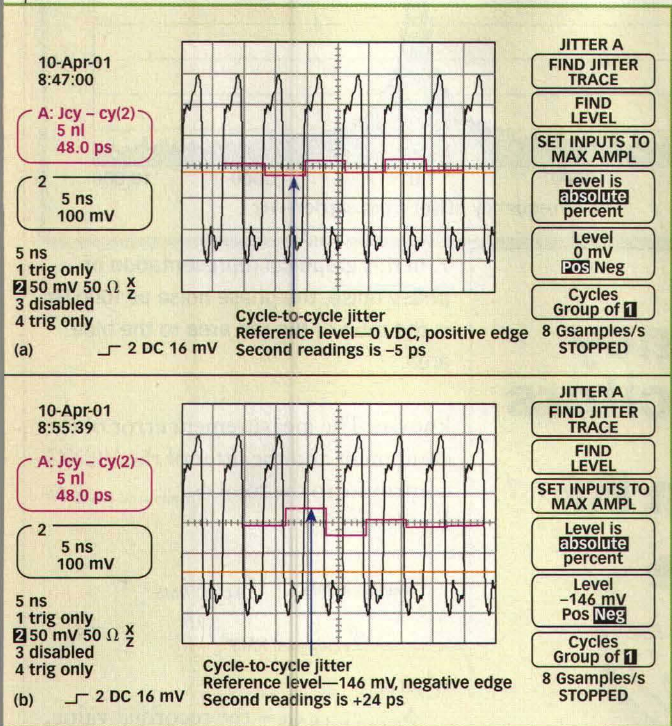
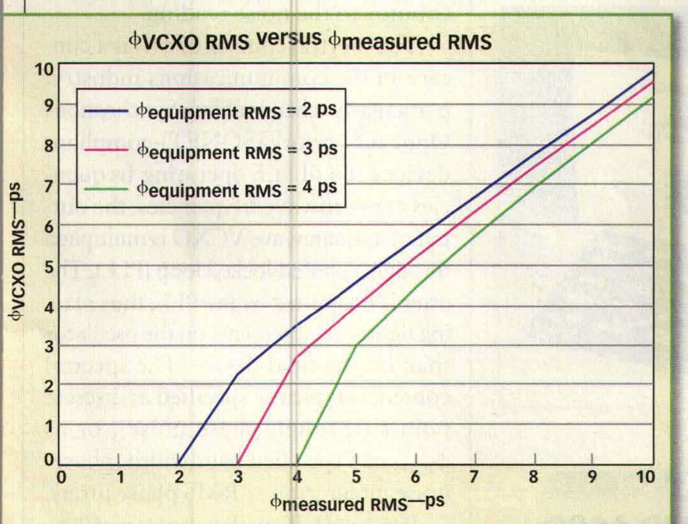


5. Cycle-to-cycle jitter was plotted for a reference level of 0 VDC, positive edge (a) and for a reference level of –146 mV, negative edge (b).

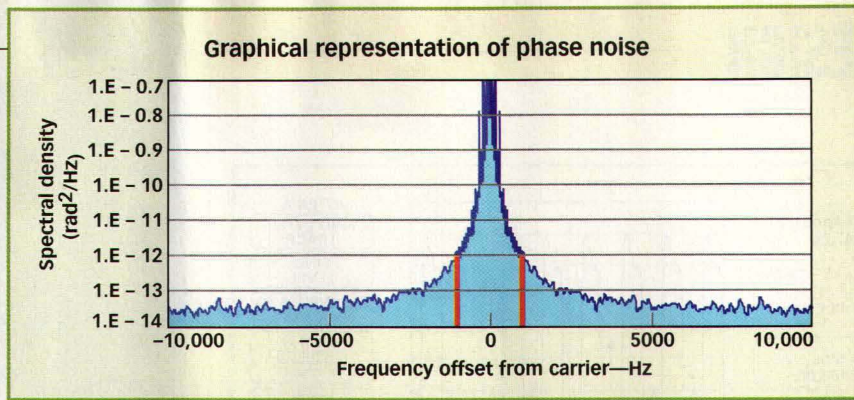
2. Good post-processing software.
3. Large single-shot memory (10 Mpoints or greater).
4. Low-noise internal clock for the sampling rate.

Appendix C (available on the long version of this article on the *Microwaves & RF* website at www.mwrf.com) discusses these requirements in more detail. With these requirements met, repeatable values down to 4-ps RMS (±1 ps cycle-to-cycle) can be obtained using digital time-domain techniques. Manufacturers of digital oscilloscopes advertise



6. A digital oscilloscope was used to plot $\phi_{\text{measured RMS}}$ versus $\phi_{\text{VCXO RMS}}$.

RMS noise floors as low as 2 ps using these methods. While this method has a floor that is relatively high for the measurement of VCXOs, the contribution to the measured $\phi(t)$ may be calculated if the jitter due to the oscilloscope and the remainder of the test setup are known. The measurement error of the equipment and the jitter of the VCXO contribute to the total $\phi_{measured\ RMS}$ as Eq. 4:



7. In this graphical representation of phase noise, the phase noise at 1000 Hz is the ratio of the red area to the blue area.

$$\phi_{measured\ RMS} = (\phi_{VCXO\ RMS}^2 + \phi_{equipment\ RMS}^2)^{0.5} \quad (4)$$

where:

$\phi_{measured\ RMS}$ = the recorded value,

$\phi_{equipment\ RMS}$ = the value due to the oscilloscope and all other equipment-related noise, and

$\phi_{VCXO\ RMS}$ = the actual jitter due to the VCXO.

The graph in **Fig. 6** is a plot of $\phi_{VCXO\ RMS}$ versus $\phi_{measured\ RMS}$ for three different $\phi_{equipment\ RMS}$ values (2, 3, and 4 ps). For an oscillator with a $\phi_{equipment\ RMS}$ value of 5 ps, the oscillator noise is comparable to the equipment noise. However, when the measured value is 10 ps, the oscillator is the major contributor to the noise reading.

The spectral content of $\phi(t)$ is a concern in the communications industry, particularly when building Synchronous Optical Network (SONET)-compliant devices. To obtain operating frequencies at microwave frequencies, the output of a squarewave VCXO is multiplied through a phased-locked loop (PLL). The jitter is magnified by the PLL, thus placing tighter requirements on the oscillator than on the final device. The spectral content is typically specified at discrete points (through phase noise), or as ϕ_{RMS} of a specified bandwidth (phase-noise integration – RMS phase jitter).

Phase noise is another measure of $\phi(t)$, but the results are displayed in the frequency domain as L(f). The displayed

results are a comparison of the noise power at undesired frequencies to the total response power, normalized to a 1-Hz bandwidth. For the oscillator in **Fig. 7**, the phase noise at 1 kHz away from the carrier is the ratio of the area of the 1-Hz bandwidth at 1 kHz (the red area) compared to the entire area under the curve.

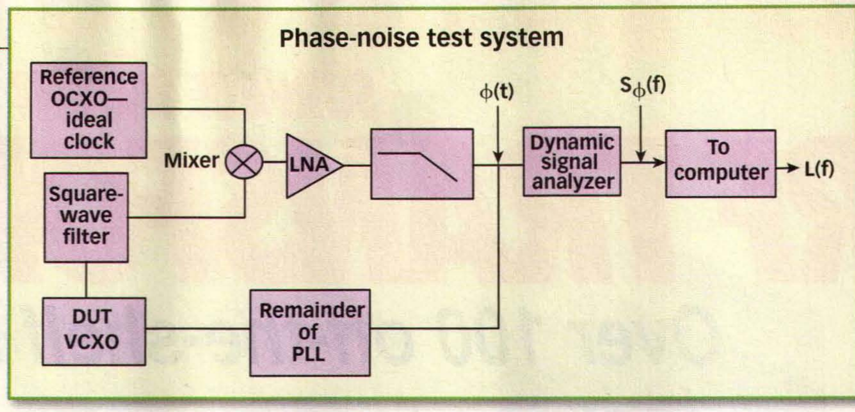
Commercially available phase-noise test equipment measure $\phi(t)$ using the PLL test setup of **Fig. 8**. The reference clock is an oven-controlled crystal oscillator (OCXO), which is approximately a suitable sine wave when compared to a VCXO, while the other is the VCXO [device under test (DUT)]. The frequency of the two devices must be close enough to enable an exact match in frequency with only minor changes to the control voltage of the VCXO.

By maintaining an approximately 90-deg. phase shift between oscillators, the mixer output measures the small phase difference between the two signals. The signal coming off the mixer is sent through an amplifier and low-pass filter. The signal that comes through the filter is a measure of $\phi(t)$. This is then measured on a dynamic signal analyzer (a high-resolution spectrum analyzer) which displays the spectral density of $\phi(t)$ in the frequency domain as $S_\phi(f)$. The phase-noise measurement equipment takes advantage of the relationship:

$$S_\phi(f) = 2L(f) \text{ for } \phi \ll 1 \text{ radian} \quad (5)$$

to plot phase noise. The base 10 logarithm of this value is then plotted in decibels below carrier/Hertz.

Part 2 of this article, to appear in next month's issue, will discuss phase noise in reference to communications applications. MRF



8. This is an example of a standard test system used to measure phase noise.

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FOR FURTHER READING

John Vig, *Quartz Crystal Resonators and Oscillators for Frequency Control and Timing Applications*, Army Communications-Electronics Command, Fort Monmouth, NJ, 1997.

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New shielding method overcomes old problems

HIGHER FREQUENCIES, smaller PCBs, easier access to components, and more stringent EMI requirements; these are the new realities for designers of communications and other RF and microwave equipment in today's markets. Shielding electronic components inside a package for noise reduction to achieve EMC is critical, but choices among various shielding techniques and products leave much to be desired. An analysis of what is available comes from a paper entitled, "Comparison of component enclosure shielding methods," by Frank Ziberna published in *ITEM Update 2001.*

Current shielding products fall into three main categories: one-piece solder mount, one-piece gasketed, and two-piece. Using any type presents a designer with trade-offs. For example, a one-piece solder-mount shield offers excellent shielding performance and low cost, but allows no access to components on the PCB and requires time-consuming desoldering when component service is required. A one-piece gasketed shield is less effective as a shield, but eliminates the need to desolder for servicing. It is fairly expensive, however, since it requires a conductive gasket and occupies more board space than a solder-mount type.

To bypass the various drawbacks, Ziberna reports on a two-piece metal shield known as a zero-clearance shield. It involves a new production method that overcomes certain problems of conventional shielding components and methods.

The shielding effectiveness of the zero-clearance is close to that of a one-piece solder-mount and better than that of a two-piece type. This is because the manufacturing process uses equipment that flattens the material to form a zero-clearance fit. Shielding effectiveness is improved over the two-piece type since the gap between the pieces is eliminated. Other benefits of the improved shield include preassembly and reduced parts count. A preassembled shield, unlike conventional shields, needs no separate lid, which means that there are fewer parts. A zero-clearance shield is provided as a single part rather than as two separate pieces. Tooling costs for the zero-clearance shield are less than those of a standard two-piece shield.

The note can be downloaded from the publication's website. For more information on shielding and the field of EMC, contact:

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Select an oscilloscope by the numbers

EXPERIENCED ENGINEERS who use oscilloscopes in their daily work probably think they know all they need to pick an instrument for any particular application. Even so, it can be useful to have a check-off list that provides a logical approach to making the right choice. This method is provided by the application note, "10 Steps to Selecting the Right Oscilloscope," from Agilent Technologies (Englewood, CO).

Step one, logically, is to decide whether an analog or digital scope is needed. That is the extent of analog-scope coverage in the note, since the modern digital types are far superior for virtually every application, and it is their features that are evaluated in the rest of the note. The following steps proceed through the key specifications and how to use them. Step two, determining bandwidth requirements, offers a discussion of the difference between repetitive (analog) and realtime bandwidth and how the latter depends on the scope's sample rate. The general rule of thumb is that realtime bandwidth should be at least three times the fundamental frequency of the fastest signal to be measured.

Step four goes into sample rate, the most important specification for single-shot measurements. A few caveats apply to sample rate. Some scopes reduce the specified sample rate when multiple channels are activated and most sample at their maximum rate only on the fastest few sweep speeds. The sample rate is reduced at slow sweep speeds. Memory depth is the subject of step six. The longer the time span that is needed to capture a signal is, the more memory is required. But a deep memory can be a disadvantage, since it slows the scope's responsiveness due to the large amount of data to be processed. Capturing glitches is examined in step seven, along with the key factors to be considered. The final step is to try the scopes under consideration before buying them, and if possible use them side by side to measure the signals in the application. Two things to pay attention to are ease of use (are the knobs and buttons convenient and intuitive?) and how quickly the instrument responds when the display is changed.

The note is available at the company's website in the Tutorial section.

Agilent Technologies, Englewood, CO 80155-3828; (800) 452-4844, Internet: www.agilent.com/find/test.

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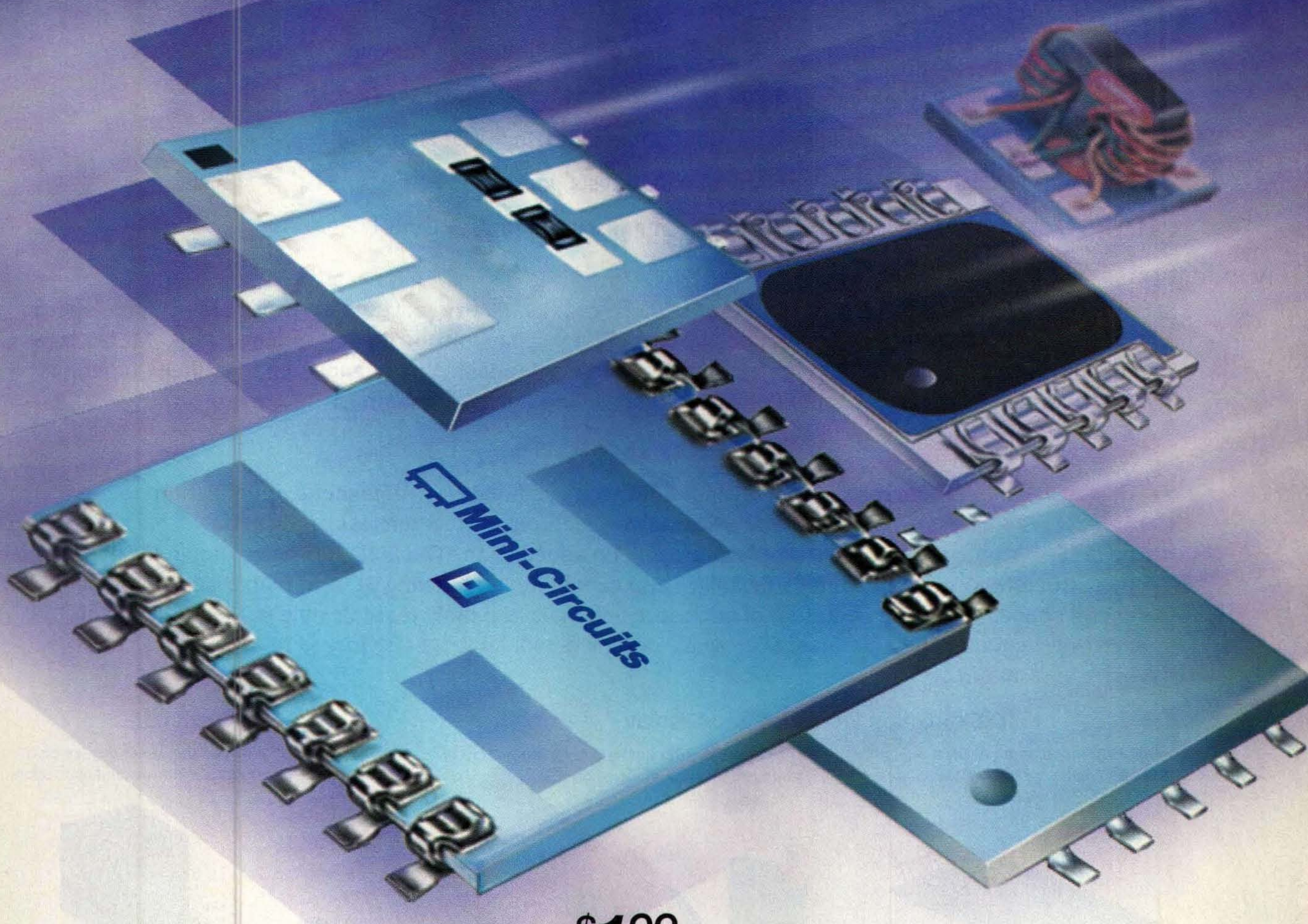

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2	90	QBA	7	340-2400	21-28	0.25-0.80	3.0-7.0	6.95
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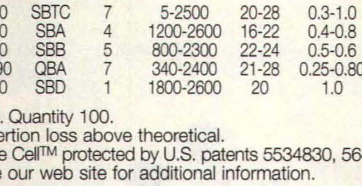

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cover story

Digital Generator Makes Programmable Noise

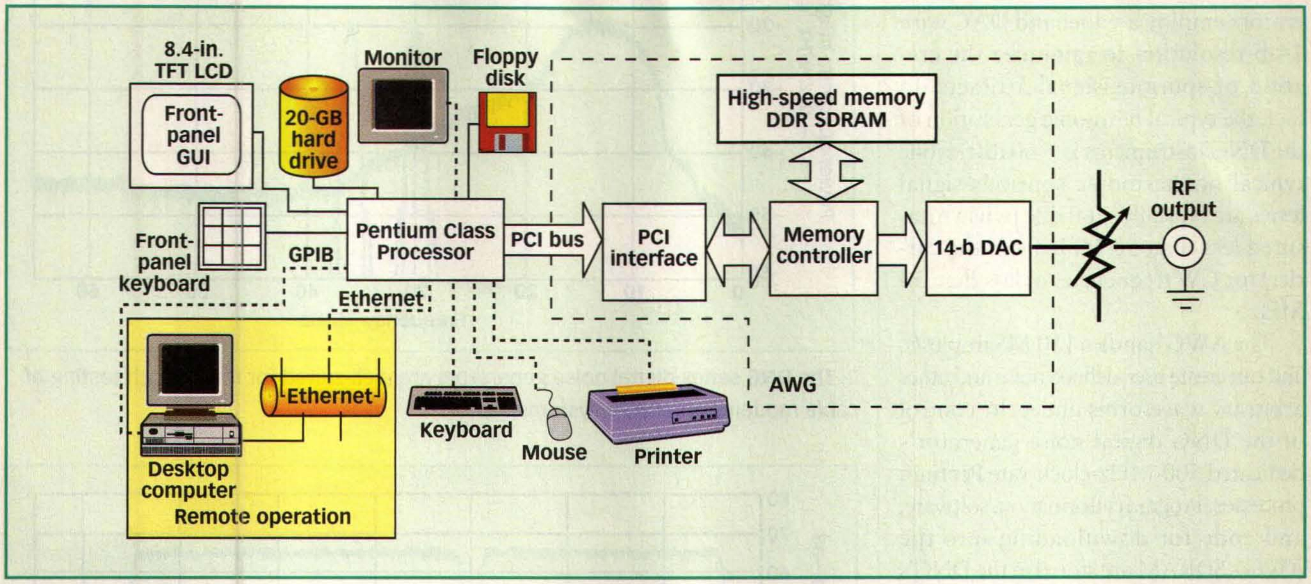
The first member in this series of digital noise generators offers a 70-MHz bandwidth with 1-Hz resolution for noise waveforms and 1-kHz resolution for CW waveforms.

JACK BROWNE
Publisher/Editor

Noise is a useful test signal for most communications systems. In the past, noise generators have been fairly simple, mainly consisting of amplified noise diodes with additional attenuation for level control. However, the new DNG digital noise generator family from Noise Com, Inc. (Paramus, NJ) brings the once-humble noise generator to a new level of sophistication. As much a computer as a signal generator, these noise generators feature arbitrary waveform generation to create precise noise and continuous-wave (CW) waveforms which accurately emulate real-world noise and interference.

The first instrument in the DNG series, the model DNG7500 **(Fig. 1)**, features a maximum 70-MHz output bandwidth (250 kHz to 70 MHz). Noise can be controlled with 1-Hz resolution. The DNG7500 can also produce CW waveforms from 250 kHz to 70 MHz with 1-kHz resolution. Noise and CW waveform outputs are generated with 0-dBm typical power.

The DNG digital noise generators provide programmable, user-specified pseudonoise and CW signal spectrums for RF, microwave, and fiber-optic equipment testing. Waveforms are generated as the result of digital codes fed to an internal arbitrary-waveform generator (AWG) which can be equipped with up to



1. This simple block diagram of the DNG7500 shows some of the key sections, including the Pentium processor and AWG.

256 Mb of synchronous dynamic random-access memory (SDRAM); standard models are equipped with 32-Mb SDRAM memory. There is a technique by which digital-code representations of noise and/or waveforms are transferred into analog output signals through a digital-to-analog converter (DAC). In the past, the resolution of DACs for these wideband applications has been limited, often resulting in poor spurious performance. But the DNG digital noise gen-

erators employ a wideband DAC with 14-b resolution to minimize the creation of spurious-signal artifacts. In fact, the typical harmonic generation of the DNG instruments is −60 dBc, while typical nonharmonic spurious-signal levels are typically −60 dBc (when measured less than 50 MHz from the carrier) for CW frequencies of less than 50 MHz.

The AWG handles 150 MSamples/s, and can create user-defined noise and other arbitrary waveforms under the control of the DNG digital noise generator's dedicated 500-MHz-clock-rate Pentium processor. Program information, software, and code for downloading into the AWG's SDRAM are stored in the DNG's 20-Gb hard-disk memory.

Software in the DNG digital noise generators is based on the Windows 98 SE operating system, so the operation of

***DNG digital noise generators** are suitable for a wide range of applications, including CATV systems and components.*

the new noise sources should be fairly intuitive to most operators. The instruments offer information on an 8.4-in. (21.3-cm) thin-film-transistor/liquid-crystal-display (TFT/LCD) screen with 640 × 480-pixel resolution. The DNG digital noise generators include interfaces for video display, keyboard, mouse, and general-purpose-interface-bus (GPIB)-equipped devices. In addition, remote operation and data access is available through integral GPIB and Ethernet ports. Output signals are available as a type-N connector with maximum VSWR of 1.50:1.

The DNG digital noise generators are suitable for a wide range of applications, including testing of cable-television (CATV) systems **(Fig. 2)** and components [such as cable modems and cable-modem termination systems (CMTS)], evaluation of wireless communications systems [such as noise-power-ratio (NPR) testing **(Fig. 3)**], electronic-warfare (EW), and satellite-communications systems, characterization of analog-to-digital converters (ADCs), and measurements on optical-communications systems and their components. The digital noise generators can create output signals based on downloads of Matlab files, and can also generate higher-frequency output signals through the addition of a custom-frequency upconverter (available for bandwidths through 40 GHz). Although they are digital sources, the DNG instruments can generate analog noise signals, such as additive white Gaussian noise (AWGN), with the following user-settable parameters: precise start and stop frequencies with brick-wall filters; tilt; notch (stop-band) filters with programmable frequency, bandwidth, and depth; and bursts with programmable duration and repetition frequency. Frequency-domain parameters are programmable from the front panel and intuitive graphical user interface (GUI). The rack-mountable DNG series instruments can generate any combination of noise and signals adjacent or occupying overlapping frequency positions with precise relative amplitudes. The instruments can be equipped for external triggering, and can be programmed remotely through an Ethernet local-area network (LAN). **Noise Com, Inc., E. 64 Midland Ave., Paramus, NJ 07652; (201) 261-8797, FAX: (201) 261-8339, e-mail: info@noisecom.com, Internet: www.noisecom.com.**

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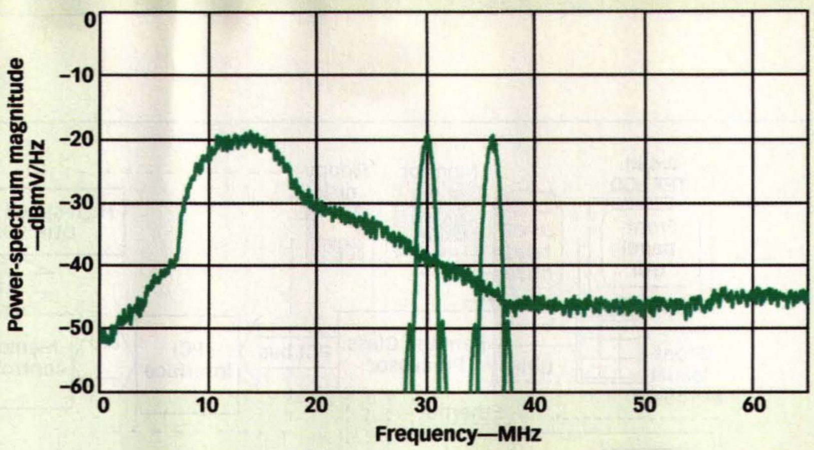
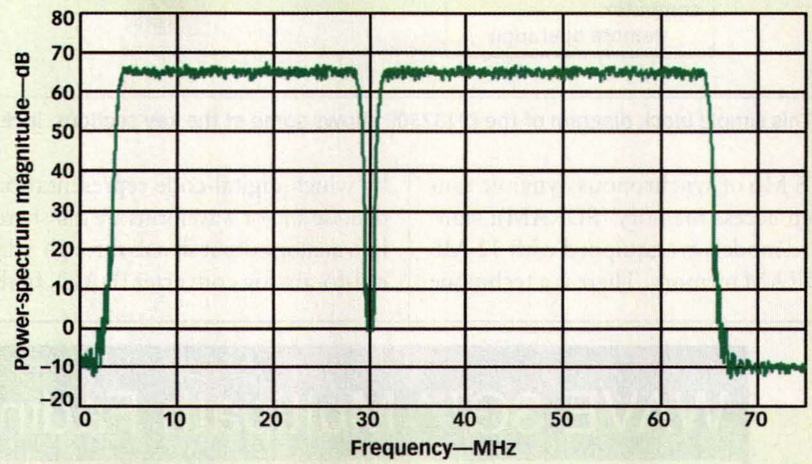
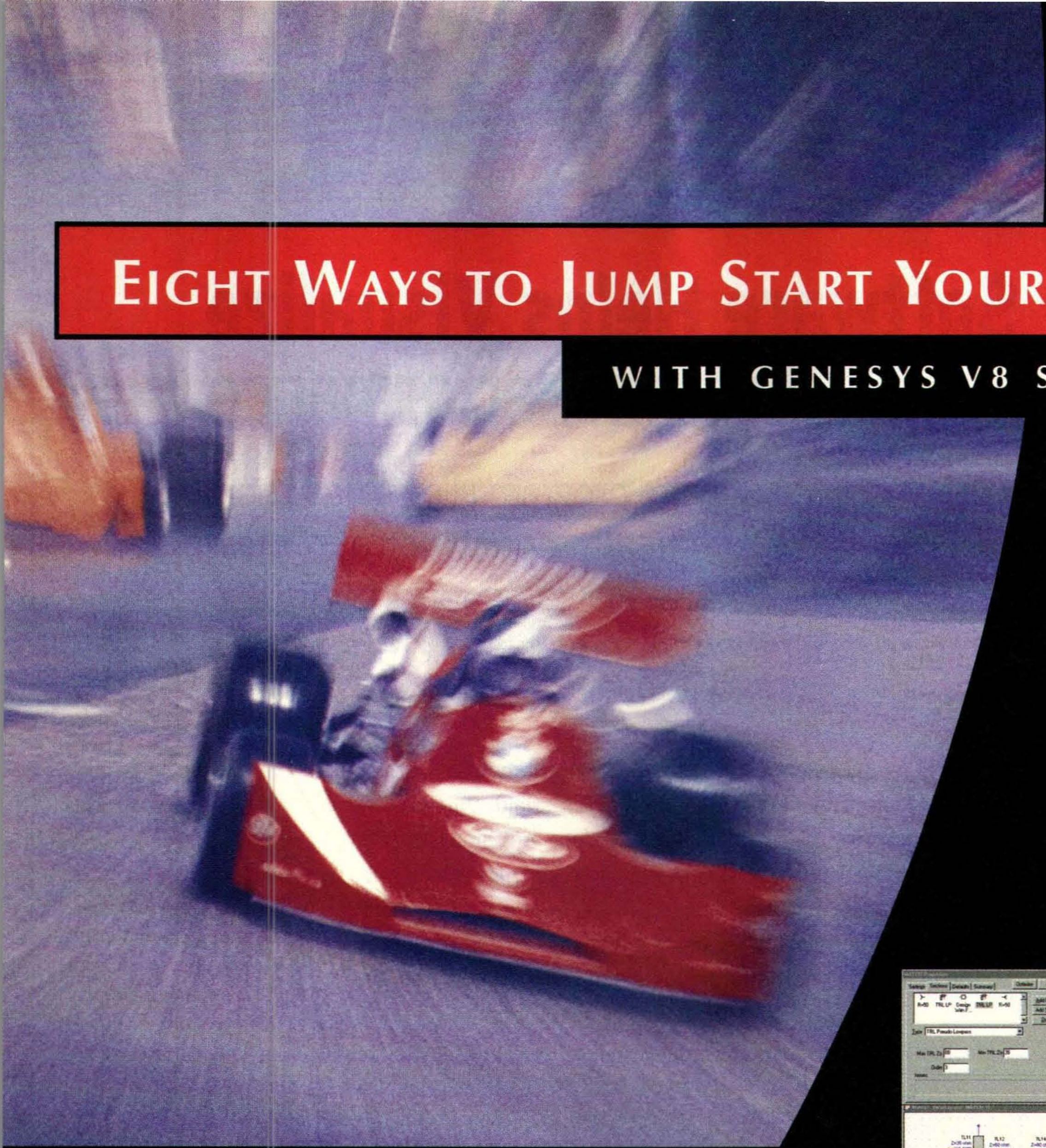


2. The DNG series digital noise generators are well-suited for return-path testing of cable modems and CATV systems.



3. The DNG digital noise generators are suitable for NPR testing of wireless communications systems.



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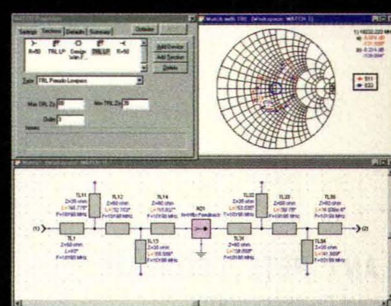

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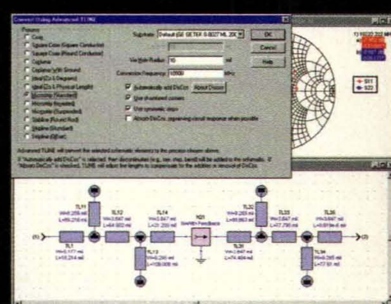

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Software Helps Visualize System Performance

This software program allows designers to methodically construct and view system-level diagrams for analysis and optimization, regardless of the design complexity.

ALAN ("PETE") CONRAD
Special Projects Editor

System-level design just got easier, with the help of Version 5.0 of SystemView from Elanix, Inc. (Westlake Village, CA). The Windows-based design, simulation, and analysis software allows operators to graphically construct mixed analog and digital system designs from a variety of function libraries. The program uses graphical tokens to represent the hundreds of functions that are found in analog and digital circuits and systems.

Some examples of algorithms and systems that can be modeled in SystemView are GSM cellular systems, CDMA cellular and PCS systems, and TDMA cellular and PCS systems. The software is suitable for modeling spread-spectrum systems, audio systems, radar systems, EW systems, beamforming networks, and DF Rxs, as well as digital-communications Rxs.

A typical design screen can include tokens and plots of performance, with click-and-drop probes allowing users to scrutinize the electrical behavior at practically any point in a design. In a typical example, the tokens are scaled in size for clarity. This sample circuit consists of a sine-wave source that feeds two ADCs which, in turn, drive two DACs. The upper ADC/DAC combination has 4-b resolution, while the lower ADC/DAC combination incorporates 8-b resolution. Differences in the resolution can be seen on the output waveform screens. SystemView allows operators to capture these systems as a "black box" or MetaSystem to eliminate crowded graphical displays. In this example, the entire design has been captured as a single MetaSystem. The design itself required only five minutes to complete with SystemView.

This latest version of SystemView features a new compiler for enhanced processing speed, which is especially helpful when evaluating large designs. The software supports simultaneous viewing of multiple MetaSystem windows. It also enables connections to, from, and between MetaSystems with open windows. The identifying numbers for tokens no longer change when one or more of the tokens are deleted and operators can easily renumber tokens from the edit menu.

This software release includes an approach to analog and digital filter design, discrete-time linear system-design capability, and continuous-time Laplace linear system-design capability. These systems are realized with graphical templates. **Elanix, Inc., 5665 Lindero Canyon Rd., Ste. 721, Westlake Village, CA 91362; (818) 597-1414, FAX: (818) 597-1427, Internet: www.elanix.com.**

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Raytheon RF Components, 362 Lowell St., Andover, MA 01810; (978) 684-8628, FAX: (978) 684-8646, Internet: www.raytheon. com.

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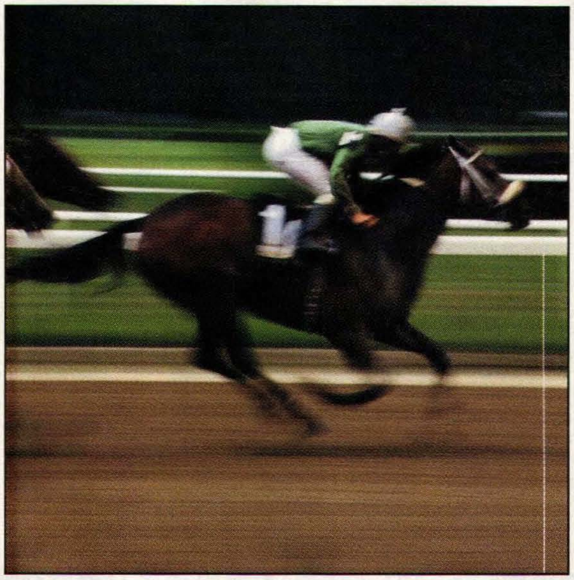

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looking back

APPROXIMATELY 17 YEARS AGO, Bob Regan and his research team at GTE Laboratories (Waltham, MA) unleashed the SIT on the world, a +100-VDC device capable of 180-W CW power at 225 MHz that could double as an electrodeless lamp.

next month

Microwaves & RF February Editorial Preview

Issue Theme: Fiber-Optic Technology

News

Optical-communications systems offer unparalleled bandwidth compared to the narrow and (usually) licensed bandwidths of wireless systems. Yet the rapid growth in fiber-optic installations and technology development during the latter 1990s came to an abrupt halt due to the economic slowdown of 2001. Still, there is optimism for renewed growth of 10-Gb/s optical-communications installations during 2002, with further development of 40-Gb/s optical-communications hardware. What are the technologies supporting this emerging high-speed market and who are the key players? Do not miss this Special Report in the February issue of *Microwaves & RF*.

Design Features

February brings a varied assortment of technology articles, ranging from the design of low-frequency probes for NMR systems to the design of a microwave power combiner. Features also cover the continuation of two article series on designing LNAs and developing short-range radio systems, as well as techniques for constructing wide-range IF amplifiers. Finally, an article on 5-GHz WLAN systems will explore how to manipulate complex OFDM signals.

Product Technology

The February Product Technology section focuses on the latest version of a powerful suite of software tools. Based on the Windows operating system, these programs combine fast EM simulation with object-based linear and nonlinear circuit simulation. Additional product features will examine a software package that helps guide the selection of antenna/cell sites for wireless communications systems, a series of high-Q ceramic filters, a novel 2-to-18-GHz phase modulator, and a line of V-band components for wideband, license-free communications at 60 GHz.